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POLLUTION AFFECTING SOUTH CHICKAMAUGA CREEK AND NICKAJACK LAKE, CHATTANOOGA, TENNESSEE

Paul Wagner, et al

Federal Water Pollution Control Administration
Athens, Georgia

February 1969

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POLLUTION AFFECTING SOUTH CHICKAMAUGA CREEK

and

NICKAJACK LAKE

Chattanooga, Tennessee

Paul Wagner, Sanitary Engineer

Robert Schneider, Aquatic Biologist

Roy Whatley, Hydraulic Engineer

Tom B. Bennett, Chemist

U. S. Department of the Interior

Federal Water Pollution Control Administration

Technical Programs

Southeast Water Laboratory

Athens, Ga.

February 1969

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I. INTRODUCTION

In a letter dated July 11, 1968, the Director of the State of Tennessee Division of Stream Pollution Control requested that the Federal Water Pollution Control Administration conduct a comprehensive waste survey of nitrogen and ammonia sources within the Volunteer Army Ammunition Plant Military Reservation at Tyner, Tennessee and, that this survey also define action necessary to establish acceptable concentrations of ammonia in the receiving waters to provide for maintenance of fish life. It was also noted in the request that excessive chlorine demands had been recorded at the Chattanooga Water Company treatment plant associated with high ammonia concentrations.

In response to this request, data were collected from October 14-21, 1968. The primary objectives of the study were to recommend pollution control measures which would insure adequate aquatic growth in the study area and also insure a high quality raw water source for the city of Chattanooga. Various chemical and physical waste parameters of Farmers Chemical Association (FCA), FCA and Friar Branches, South Chickamauga and Citico Creeks, and Nickajack Lake were measured. Bioassay, hydrological and water quality studies were performed and these data were evaluated in order to define the causes of excessive chlorine demands at the water plant and to recommend necessary waste abatement measures.

II. SUMMARY AND CONCLUSIONS

Ammonia and other nitrogenous and carbonaceous wastes discharged by the Farmers Chemical Association (FCA) and General Aniline and Film's Textile Chemical Division plants seriously pollute Friar Branch from the FCA input to the confluence with South Chickamauga Creek. Concentrations of ammonia in Friar Branch were recorded in excess of 100 mg/l and bioassay studies indicated acute toxicity to aquatic life. Phenolic concentrations of 10 ppb were also observed below the General Aniline and Film Corporation discharge. The General Aniline and Film installations were formerly known as Southeast Polymers and Burkhart-Schier.

Ammonia concentrations in South Chickamauga Creek exceeded 4 mg/l below the Friar Branch confluence. This is nearly triple the maximum level considered acceptable for fish and aquatic life propagation. There is a significant reduction of benthic organisms in South Chickamauga Creek from above to below the confluence with Friar Branch. Pollution indicators such as chemical oxygen demand, total organic carbon, coliform and alkalinity demonstrated substantial waste sources discharging to the south side of South Chickamauga Creek below river mile 2.1. Bioassay results demonstrated that these wastes are toxic to fish life. Companies discharging wastes in this reach include Davidson Chemical, a division of W. R. Grace and Company, Ray Ser Dyeing, DeSoto Chemical's, Special Products Division, Mueller and Alco.

Ammonia concentrations at the mouth of Citico Creek were 50% higher than at the mouth of South Chickamauga Creek (3.8 mg/l vs. 2.6 mg/l). Excessive phenolic concentrations (30 ppb) and alkalinity (163 mg/l) were also observed at this location. Dissolved

oxygen was essentially zero. The major waste discharge to Citico Creek is the Southern Railway Yards.

Dye studies and water quality data showed no definite stratification in Nickajack Lake at flows of about 30,000 cubic feet per second (cfs). Ammonia and total organic nitrogen concentrations near the Chattanooga water supply intake averaged 0.1 mg/l and 0.42 mg/l respectively. Chemical oxygen demand concentrations of 18.5 mg/l indicated that the water supply intake is affected by pollutional discharges in the area. Coliform concentrations in Nickajack Lake also reflect the influence of waste discharges.

Chlorine demand at the water plant is directly related to ammonia concentrations at the intake within the range of 0 to 0.7 mg/l of ammonia. At concentrations exceeding 0.7 mg/l, increasing ammonia concentrations account for about one-third of the increased chlorine demand with other materials accounting for the remaining two-thirds. Chlorine demand significantly increased at flows in Nickajack Lake less than 14,000 cfs on a seven-day average basis. It is hypothesized that at flows less than 14,000 cfs, stratification occurs in Nickajack Lake permitting wastes from South Chickamauga Creek with decreased dilution and, consequently, increased concentrations to reach the water plant intake. In addition, wastes from Citico Creek whose mouth is located about fifty feet downstream from the intake also are drawn into the intake under the reduced flow and stage conditions in Nickajack Lake.

The major sources of ammonia to South Chickamauga Creek are: the Farmers Chemical Association (FCA) with 1315 lbs/day; General Aniline and Film (GAF) discharges with an estimated 1970 lbs/day;

and the Brainerd sewage treatment plant with 390 lbs/day. The major source of ammonia within the FCA plant is the anhydrous ammonia operation accounting for 43% of the total discharged. To maintain a maximum ammonia concentration of 1.5 mg/l during the lowest three-day discharge occurring in twenty years in South Chickamauga Creek for propagation of fish and aquatic life, a 91% reduction in ammonia from present discharge levels is required. On a proportional basis, the Brainerd STP should discharge not more than 34 lbs/day; GAF's Southeast Polymer, Burkhart-Schier combined waste should not exceed 178 lbs/day; and FCA ammonia discharge should be reduced to 119 lbs/day. Based on a 650,000 gallon per day waste flow from FCA, the ammonia concentration in the effluent should not exceed 22 mg/l. These figures should be considered maximum discharges, not average values. Equivalent reductions should also be made in the nitrogen and nitrite-nitrate concentrations of these discharges.

More important than propagation of fish and aquatic life, however, is the fact of a definite health hazard to the population of Chattanooga due to organic contamination of the water supply source by the untreated and inadequately treated waste discharges in South Chickamauga Creek, Friar Branch, and Citico Creek. It should be the first order of priority in any area pollution control program to provide the highest degree of practicable treatment and removal for the wastes resulting from the above named discharges and Davidson Chemical Division of W. R. Grace Co., Ray Ser Dyeing, Mueller, Special Products, Southern Railroad, Alco and any other effluents which may affect the water plant intake. In addition, the location of the intake should be extended farther upstream and away from the shoreline.

On a long-term basis, the most effective abatement plan would remove these effluents from the immediate drainage basin. The feasibility of extending the Chattanooga municipal sewerage system to intercept all of these waste sources should be investigated and, if warranted, should be implemented at the earliest possible opportunity. Such action would also have the benefit of recovering Friar Branch for fish propagation provided adequate flow conditions could be maintained should the State of Tennessee desire to classify this intrastate waterway. The wastes being discharged to Friar Branch at present, make this impossible, even with the previously recommended degree of removal, because of the inadequate dilution.

Because of the pronounced contamination of the Chattanooga water supply at flows in Nickajack Lake of less than 14,000 cfs by the wastes discharged into the highly polluted Citico Creek, the confluence of Citico Creek with Nickajack Lake should be diverted from its present location to a point farther downstream in Nickajack Lake. In the short term, while the waste abatement program is proceeding and the diversion is being constructed, the Tennessee Valley Authority should maintain a minimum flow of 14,000 cfs in Nickajack Lake.

III. AREA

Farmers Chemical Association (FCA) is located near Tyner, Tennessee, northeast of the city of Chattanooga, within the reservation boundary of the Volunteer Army Ammunition Plant. About .65 million gallons/day (mgd) of waste generated in its commercial fertilizer production is directed south into two consecutive holding basins, and then into a shallow creek which mainly consists of effluent from FCA. This creek joins Friar Branch one mile below the FCA outfall and just east of Standifer Gap Road.

South Chickamauga Creek rises in northern Georgia, flows north into Tennessee and is joined by West Chickamauga Creek north of the Georgia-Tennessee border. About four miles downstream from the confluence, South Chickamauga Creek is joined by Friar Branch, due north of the Chattanooga Municipal Airport. The flow in South Chickamauga below the confluence with Friar Branch was gauged at an average of 91 mgd or 140 cubic feet per second (cfs) during the survey.

South Chickamauga Creek continues in a northerly direction for approximately eight miles and empties into the Tennessee River 2.8 miles downstream from Chickamauga Dam at river mile 468.2. The Tennessee River is impounded below the confluence at river mile 424.6 by Nickajack Dam, forming the reservoir known as Nickajack Lake. Depth and flow through the Nickajack impoundment are controlled by the two Tennessee Valley Authority (TVA) hydroelectric dams at either end. The private water company serving the city of Chattanooga utilizes Nickajack Lake for its source of drinking water supply. The water treatment plant is located on the southern bank of the impoundment near Citico Bar at river mile 465.3 about six miles downstream from

Chickamauga Dam. Water emptying from South Chickamauga Creek into Nickajack Lake must travel downstream 2.7 miles to reach the intake point of the water plant. The total downstream distance from FCA to the Chattanooga water plant totals about 15 miles.

Citico Creek, another tributary of the Tennessee River, enters the reservoir at river mile 465.3 about fifty feet downstream from the water plant intake. The creek is formed by several ditches fanning out in all directions and flowing generally from the vicinity of the Southern Railroad Yards. Flow is composed primarily of land drainage and industrial discharge.

The study area is shown in FIGURE 1.

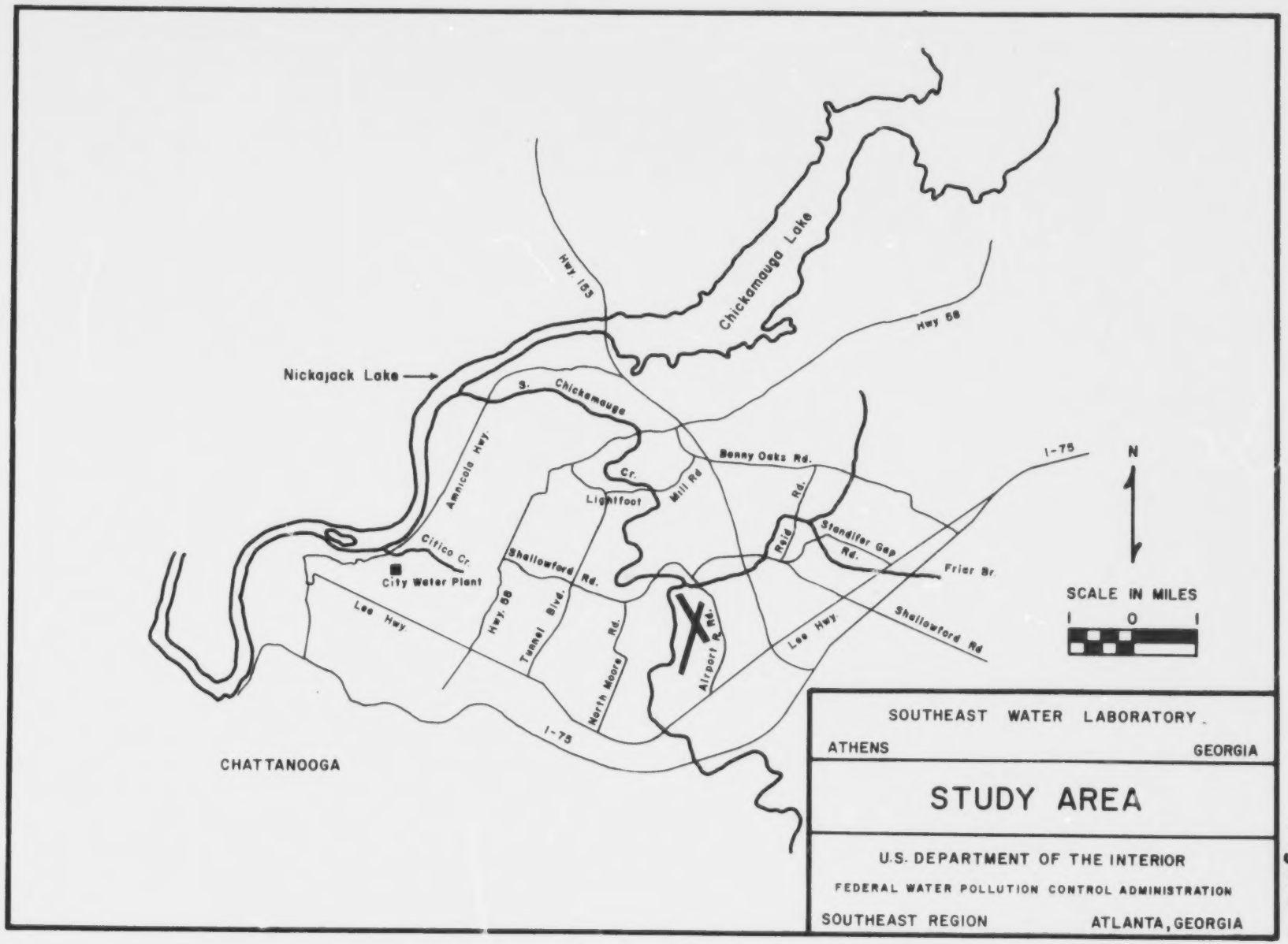
Chickamauga Lake
Hwy 153
Hwy 58
Nickajack Lake
S. Chickamauga Cr.
Amnicola Hwy.
Benny Oaks Rd.
I-75
N
Lightfoot Mill Rd
Reid Rd.
Standifer Gap Rd.
Frier Br.
Citico Cr.
City Water Plant
Shallowford Rd.
Lee Hwy.
Hwy. 58
Tunnel Blvd.
North Moore Rd.
Airport Rd.
Lee Hwy.
Shallowford Rd
I-75
CHATTANOOGA
SCALE IN MILES
1 0 1
SOUTHEAST WATER LABORATORY
ATHENS GEORGIA
STUDY AREA
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTHEAST REGION ATLANTA, GEORGIA

Figure 1

IV. BACKGROUND

Chattanooga Water Company

The Chattanooga Water Company has been experiencing an excessive chlorine demand in their treatment processes. The treatment plant is operated by a commercial firm contracted to supply water to the city of Chattanooga. The water company has stated that nearly four times the normal consumption of chlorine was required on occasions to maintain a free chlorine residual in the city's drinking water. This situation appeared to correlate with high ammonia concentrations detected in the raw water during the water plant's routine laboratory analysis.

A survey was performed in the area on May 21 and 22, 1968, by the Tennessee Division of Stream Pollution Control which indicated that the excessive demand was related to ammonia discharge at FCA and flow regime in the reservoir.(1)

On September 13, 1968, the City Water Company of Chattanooga, called the Director of Health, TVA, requesting assistance in preventing the occurrence of a health hazard due to the possible lack of effective disinfection of the water supply caused by excessive chlorine demands. The basic problem was the inability of the water company to maintain a free chlorine residual between 1.0 and 1.5 mg/l. With the chlorinators operating at full capacity, only 0.4 mg/l residual chlorine could be maintained on September 13, 1968. On this date it became necessary to

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(1) Ammonia Nitrogen-Chlorine Demand Field Survey of Friar Branch, S. Chickamauga Creek, Tennessee River in the Chattanooga Vicinity, (May 21-22, 1968); Tennessee Stream Pollution Control Board.

apply 130 pounds of chlorine per million gallons of water. During periods of normal chlorine demand, the rate is about 35 pounds per million gallons of water. The water company attributed the high chlorine demand to high ammonia concentrations in its raw water supply.

The water company's immediate concern was that TVA had lowered the stage of Nickajack Reservoir two feet for control of milfoil weed and were planning reduced discharges over the week-end from Chickamauga Dam due to lessened hydro-electric demand during the week-end. The company felt that the combination of lower stage and excessive discharges of ammonia would not permit the maintenance of an adequate chlorine residual. Chlorination requirements were met when TVA increased the discharge rate and the volume of effluent from Farmers Chemical Association was reduced.

Farmers Chemical Association

FCA is presently occupying a large portion of the Federal reservation owned by the Volunteer Army Ammunition Plant (VAAP) under the terms of a 99-year lease. The total production of this plant is divided between its commercial chemical fertilizer production and its acid synthesis in support of VAAP's explosives manufacturing. The chemical fertilizer produced includes anhydrous ammonia, urea, nitric acid and various nitrate and nitrite compounds. The wastes from the fertilizer operation are segregated from the production wastes generated in support of Atlas Chemical Company, the Government TNT contractor and are discharged into a creek which empties to Friar Branch. The remainder of the wastes, amounting to about 95% of the plants total effluent volume is directed north where it is combined with that of the TNT production waste water and is discharged into Waconda Bay and then to Chickamauga

Lake. The liquid wastes discharged to the south originate as cooling water blowdown, waste water from air pollution abatement scrubbers, and also from spills, leaks and other incidental losses along the production line. A recent modernization of the plant has improved the quality of water discharged. The plant has attempted to locate and eliminate discharge to its waste ditches by replacement and/or modification of its operating equipment and through cooling water reuse, diking and by generally more stringent control of spillage and production loss.

During May 21-22, 1968, the State of Tennessee reported that direct nesslerization analysis for ammonia showed an average of 900 mg/l ammonia to be in the discharge of the plant.(2) More recent analysis performed in October 1968, by TVA authorities and by an independent laboratory showed these levels to be averaging from 300-400 mg/l. The plant has two holding ponds connected in series. However, at present, waste discharged into the ponds flows directly through. The primary use of the ponds is for storage in the case of major spills. No other treatment is afforded to the chemical waste by FCA. A sewage plant, employing trickling filtration is operated by FCA for treatment of sanitary waste generated by the 2700 employees of the VAAP. This waste is also directed toward Friar Branch.

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(2) Ibid.

V. WATER USES

Friar Branch, South Chickamauga Creek and Citico Creek

The Tennessee Stream Pollution Control Board, in its 1967 publication on water quality standards, has designated South Chickamauga Creek in the following use classifications: industrial water supply, fish and aquatic life, irrigation, livestock watering and wildlife.(3) Basic criteria outlined for waters in these categories include: dissolved oxygen of 5.0 mg/l (except in limited sections); maximum temperature of 93°F with no greater than a 10°F increase; total dissolved solids 500 mg/l; and pH 6.5 to 8.5. The state has not classified Friar Branch. However, it was observed that the stream is utilized for livestock watering and wildlife and would be suitable for fish and aquatic life and irrigation upstream from its confluence with the FCA waste. The close proximity of several industrial firms to these streams has also led to their use for waste disposal. The State of Tennessee has reported color, taste and odor to be problems in South Chickamauga Creek between river mile 9.2 to the confluence with Nickajack Reservoir, and toxic wastes to be present from river mile 2.1 to the confluence.(4) Citico Creek has not received a designated water use classification. Although the stream might be utilized as a source of industrial water supply, its apparent major use at this time is for waste transport.

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(3)Water Quality Criteria for the State of Tennessee, Tennessee Stream Pollution Control Board, Tennessee Department of Public Health, Tennessee, 1967.

(4)Ibid.

Nickajack Lake

The Tennessee River, including the northern portion of Nickajack Lake, above the confluence of Chattanooga Creek from river mile 460.6 to 530.0 has been classified by the state for the following uses: domestic raw water supply, industrial water supply, recreation, fish and aquatic life, livestock watering and wildlife, irrigation and navigation.(5) These classifications call for values of dissolved oxygen 5.0 mg/l (except in limited sections); pH 6.5 to 8.5; maximum temperature 93°F with no increase greater than 10°F; total dissolved solids of 500 mg/l; coliform group 10,000 per 100 ml; and fecal coliform 1,000 per 100 ml. With the construction of the two hydro-electric dams, Nickajack and Chickamauga, TVA has established a highly desirable recreational center in Nickajack Lake. Boating and fishing are popular uses of the reservoir. The park constructed near Chickamauga Dam is utilized for boating and picnicking, as well as sport fishing. Recreational utilization for the impoundment during the year 1960 was estimated to be 118,500 person-days. The city of Chattanooga and several surrounding communities utilize the reservoir as their source of raw water.

The State has cited taste and odor as unacceptable water quality parameters in the study area of Nickajack Lake. This condition is said to exist from river mile 468.2 to 465.5.(6)

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(5) Ibid., Table 2.

(6) Ibid., Table 1.

VI. WASTE DISCHARGES

General

Most of the data presented in this section were abstracted from the 1964 survey report of the Chattanooga area, conducted by the Tennessee Division of Stream Pollution Control.[7]

All waste amounting to about 1 cfs normally leaving FCA's fertilizer production and the sanitary waste from VAAP is directed into a small creek. No other source of waste flows into this stream. Rainfall runoff provides the only other flow.

Friar Branch

The Burkhart-Schier Chemical Company produces textile chemicals and latex compounds. Waste is retained in the company's oxidation pond. However, there is an undetermined volume of discharge to Friar Branch. The effluent has a milky color with high turbidity. Southeast Polymers Inc., the second industry to discharge waste to Friar Branch, produces synthetic latex. Industrial wastes consist of highly colored and turbid waters with trace amounts of soaps and synthetic latex solids. A series of three ponds are utilized to settle out solids before the waste is allowed to enter the stream. Field observations indicated that discharges from these sources are intermittent. Both of these installations are part of General Aniline and Film's Textile Chemical Division.

---

(7) Stream Pollution Survey of the Chattanooga Area, Tennessee Department of Public Health, Stream Pollution Control, (1964).

South Chickamauga Creek

Two major municipal sewage treatment plants in Tennessee discharge into South Chickamauga Creek above the confluence with Friar Branch. The East Ridge Treatment Plant is located on Spring Creek, a tributary of West Chickamauga Creek, which joins South Chickamauga Creek about four miles above the Friar Branch confluence. The Brainerd Sewage Treatment Plant (STP) is located 2.3 miles above Friar Branch confluence. Both plants employ secondary sewage treatment with a sewered population of approximately 43,000. Waste discharged into South Chickamauga Creek from these plants is reported to be 5100 population equivalents (PE) all of which receives chlorination.

The Lutex Chemical Corporation discharges to South Chickamauga Creek below the Brainerd effluent and above the confluence with Friar Branch. The waste is highly colored. Other characteristics of this waste discharge are not known.

Below the confluence of Friar Branch, several industrial concerns empty waste into South Chickamauga Creek.

Swift and Company Agricultural Chemical Division produces chemical fertilizer, utilizing phosphate rock, sulfuric acid, potassium salts and ammonia as raw materials. Waste water containing high fluoride and solids concentrations is discharged to two sedimentation basins. The State report indicates that no discharge is made from the basins into South Chickamauga Creek. The firm is located at river mile 4.5.

Ray-Ser Dyeing Company is engaged in the processing and dyeing of synthetic yarns. Waste originating in the dyehouse is not treated and is discharged via a drainage ditch, into South Chickamauga Creek. About 10,000 gallons per day are discharged having BOD and color.

The discharge is at river mile 2.1.

Fireplace furnishings and lighting fixtures are fabricated by the Special Products plant of DeSoto, Inc. located near the Ray-Ser Company. Metal plating and bonderizing operation wastes are directed to a lagoon before discharge to South Chickamauga Creek. Wastes contain heavy metals, cyanides and phosphates and may be toxic to fish life. The discharge is at river mile 2.1.

Davidson Chemical Division of W. R. Grace Company (formerly Vitro Chemical Company), located at river mile 1.3, manufactures polishing oxides, thorium-magnesium hardener, thorium granules, rare earth chlorides, fluorides and other chemicals. Waste producted including caustic soda, trisodium phosphate, chlorides and fluorides are discharged to a lagoon and then flow into the creek at the rate of about 100,000 gallons per day. The effluent contains high concentrations of solids, turbidity, chlorides and alkalinity and is caustic. A new lagoon has recently been placed into operation.

Alco Chemical Company utilizes caustic soda, carbon disulfide, amines, methyl acrylate and zinc sulfate in its production of rubber and textile manufacturing aids. The effluent from this operation is alkaline, contains zin, solids and carbon disulfide. It is treated in a series of three sedimentation basins and then discharges at river mile 1.0.

The Mueller Company is also reported to discharge waste into South Chickamauga Creek below river mile 2.1. No information regarding the character of this waste was reported.

Nickajack Lake

Several industrial concerns empty waste either directly into the lake or through the many streams flowing into it. Among the major waste producers is the E. I. DuPont de Nemours Company plant located five miles upstream and on the opposite shore from the water plant intake. This plant produces nylon yarns and wastes contain such by-products as acids, caustics, solids and organic material. The 7.3 mgd discharge contains the waste of a population of 9521 people. No treatment is provided on the industrial waste discharge. This firm discharges to Nickajack Lake at river mile 470.0.

Also flowing into Nickajack Lake, entering just downstream from the water plant is Citico Creek. Several industrial firms dump waste into Citico Creek, the major polluter being the Southern Railway Yards. The servicing of rail vehicles in the Southern Railway Yards has resulted in concentrations of oil and petroleum products in Citico Creek. Following storms when normal waste treatment measures are bypassed, oil concentrations have been measured at 170,000 mg/1. Even though Citico Creek empties into Nickajack Lake below the water plant intake, oily slicks have been observed in the settling basins of the water treatment plant after periods of low river flow. The other waste discharges above the Southern Railway Yards cause extensive discoloration. No information on sources or characteristics of these wastes was obtained. They include Cumberland Case Company, Cutter Laboratories and United Hosiery Mills.

Location and character of waste discharges are shown in TABLE I and illustrated in FIGURE 2.

TABLE I

WASTE DISCHARGES

Name of Industry	Principle Product	Waste Characteristics Vol.(mgd)	Composition	Type Treatment	Receiving Stream	Outfall Location
Farmers Chemical Assn.	ammonia, urea, nitrates & nitrites	0.65	sanitary, process & cooling	Secondary & setting ponds	Friar Br. to S.Chick. Creek	Friar Br. mile 2.9
Burkhart-Schier Chem. Co. of G.A.F.	textile chemicals, latex compounds	--	--	Holding Pond	Friar Br. to Chick. Creek	Friar Br. mile 0.6
Southeast Polymers, Inc. of G.A.F.	synthetic latex compounds	--	--	Sedimentation	Friar Br. to Chick. Creek	Friar Br. mile 0.7
Swift & Co. Agri. Chem.Div.	Chemical fertilizer	--	--	Sedimentation	S.Chick. Creek	S.Chick. Creek mile 4.5
Mueller Company	hydrants & valves	--	Process, Sanitary	Sedimentation, Secondary	S.Chick. Creek	S.Chick. Creek mile 2.1
Special Products Div. of DeSoto Chem.Co.	fireplace furnishings & lighting fixtures	--	Process	--	S.Chick. Creek	S.Chick. Creek mile 2.1
Ray-Ser Dyeing Company	dyed synthetic yarns	0.01	Organic & color	--	S.Chick. Creek	S.Chick. Creek mile 2.1
Davidson Chemical Div.of W.R.Grace Company	rare earth chemicals	0.10	Sanitary & Process	Secondary settling pond & lagoon	S.Chick. Creek	S.Chick. Creek mile 1.3
Alco Chemical Company	textile & rubber manuf.aids	0.014 0.169	Process Cooling	Sedimentation None	S.Chick. Creek	S.Chick. Creek mile 1.0

CONT'D.

TABLE I CONT'D.

Name of Industry	Principle Product	Waste Characteristics		Type Treatment	Receiving Stream	Outfall Location
		Vol.(mgd)	Composition			
Cumberland Case Company	Dairy & Poultry Equip.	0.282	Cooling & washing	--	Citico Creek	--
Cutter Laboratory	Hospital Solutions & Equip.	0.169 0.083	Cooling process	--	Citico Creek	--
Southern Railroad System	--	--	Oil waste, wash water	Oil separators	Citico Creek	--
United Hosiery	Cotton Clothing production	--	Boiler blowdown	--	Citico Creek	--
E.I. DuPont Company	Nylon	6.030 0.076	Industrial & cooling Sanitary	-- Secondary	Tenn. River	Nickajack Res. mile 470.0

-- = unknown

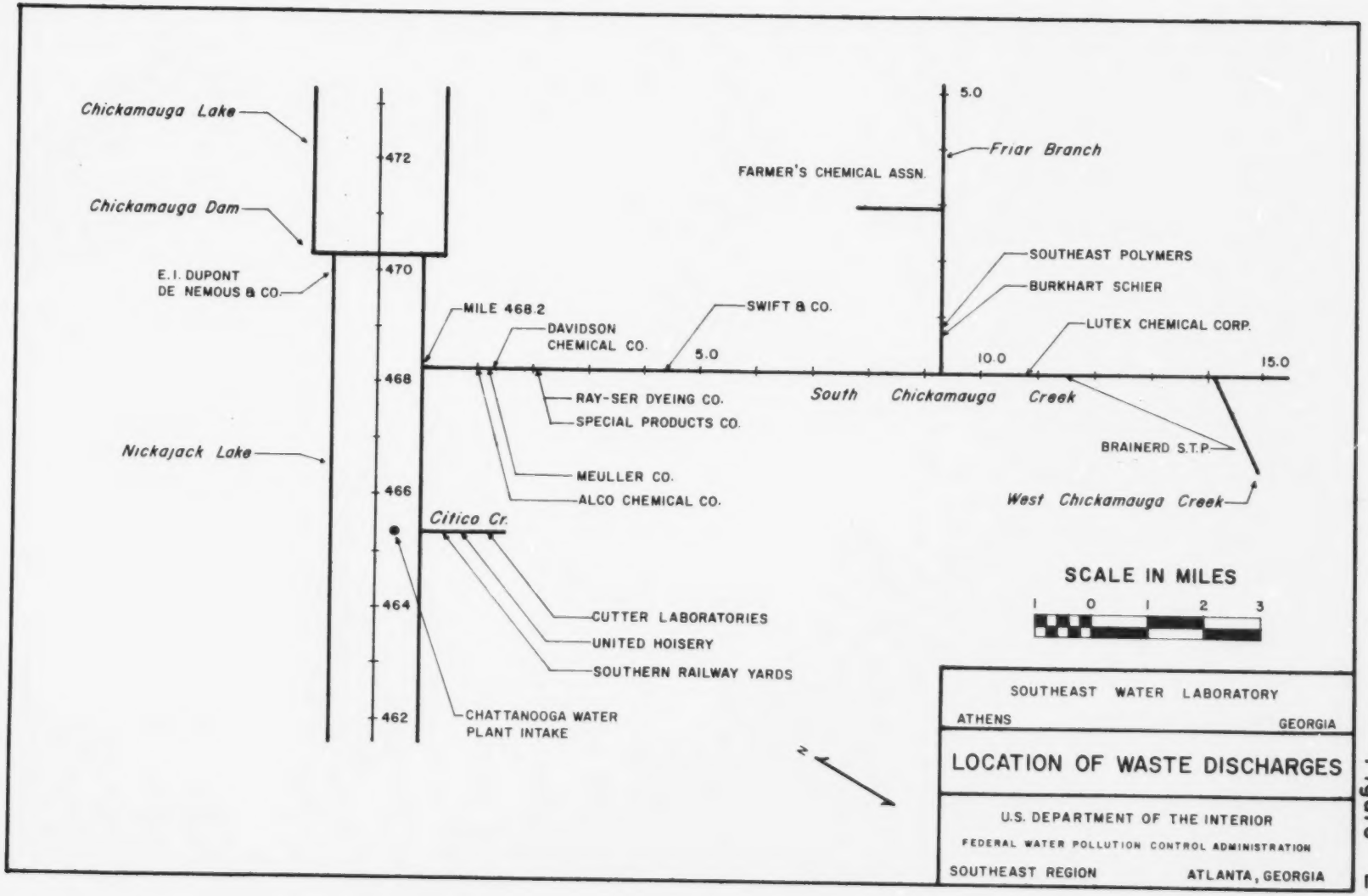

Chickamauga Lake
Chickamauga Dam
E. I. DUPONT DE NEMOUS & CO.
Nickajack Lake
472
470
468
466
464
462
MILE 468.2
DAVIDSON CHEMICAL CO.
SWIFT & CO.
5.0
FARMER'S CHEMICAL ASSN.
5.0
Friar Branch
SOUTHEAST POLYMERS
BURKHART SCHIER
LUTEX CHEMICAL CORP.
10.0
15.0
South Chickamauga Creek
RAY-SER DYEING CO.
SPECIAL PRODUCTS CO.
MEULLER CO.
ALCO CHEMICAL CO.
BRAINERD S.T.P.
West Chickamauga Creek
Citico Cr.
CUTTER LABORATORIES
UNITED HOISERY
SOUTHERN RAILWAY YARDS
CHATTANOOGA WATER PLANT INTAKE
SCALE IN MILES
1 0 1 2 3
N
SOUTHEAST WATER LABORATORY
ATHENS GEORGIA
LOCATION OF WASTE DISCHARGES
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTHEAST REGION ATLANTA, GEORGIA

Figure 2

VII. SURVEY PROCEDURES

WATER QUALITY STUDY

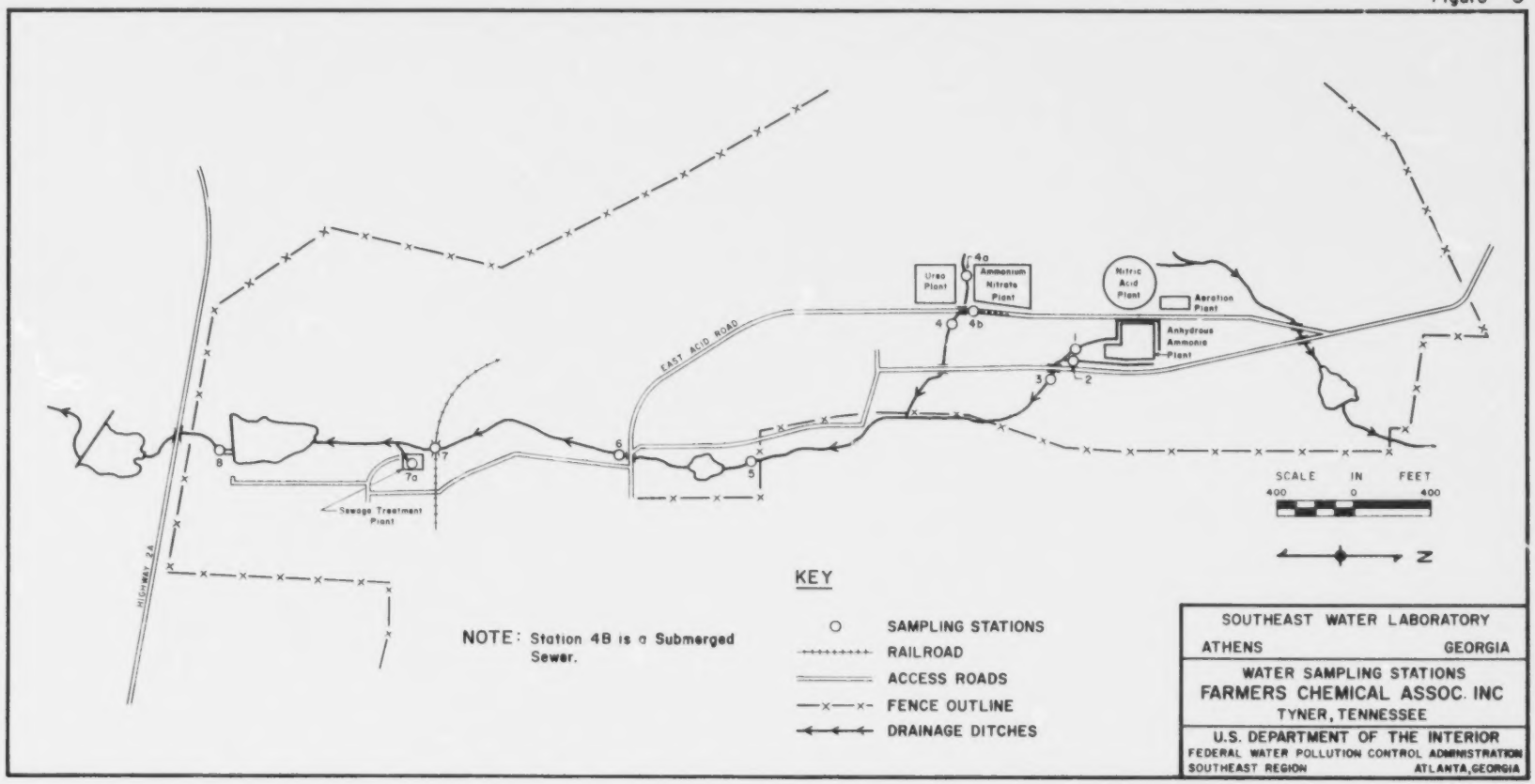
FCA

An in-plant survey of waste sources within FCA was made to evaluate sources contributing major quantities of ammonia and other nitrogen compounds to the fertilizer manufacturing portion of the plant's waste discharge. The four major contributing processes, acid, urea, ammonium nitrate production, anhydrous ammonia synthesis, were isolated, and samples collected from surface drainage ditches from these processes were analyzed for pH, temperature and nitrogen series. The domestic sewage treatment facility, which employs secondary treatment, was also evaluated to determine its individual contribution to the plant's waste discharge. Samples were taken at the outfall of the second holding pond to determine final waste discharge characteristics. Samples from each station were taken once each day for a three-day period, during the morning hours between 9:00 AM and 12:30 PM. Sampling points are shown in FIGURE 3.

Friar Branch, Chickamauga Creek and Citico Creek

Sampling stations were established along Friar Branch and South Chickamauga Creek at locations shown in FIGURE 4. Samples were taken from the stream channel at mid-depth once each day for a three-day period. Parameters included immediate measurements for temperature, pH and dissolved oxygen. Samples were taken for analysis of nitrogen series, COD and total organic carbon. Nitrogen series concentrations throughout this report are expressed in terms of nitrogen according to standard procedure but are discussed in terms of the parameter from which the nitrogen was calculated. Therefore, caution should be exercised

Figure 3


Urea Plant
Ammonium Nitrate Plant
Nitric Acid Plant
Aeration Plant
Anhydrous Ammonia Plant
EAST ACID ROAD
Sewage Treatment Plant
HIGHWAY 24
SCALE IN FEET
400 0 400
N
KEY
SAMPLING STATIONS
RAILROAD
ACCESS ROADS
FENCE OUTLINE
DRAINAGE DITCHES
NOTE: Station 4B is a Submerged Sewer.
SOUTHEAST WATER LABORATORY
ATHENS GEORGIA
WATER SAMPLING STATIONS
FARMERS CHEMICAL ASSOC. INC
TYNER, TENNESSEE
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTHEAST REGION ATLANTA, GEORGIA

in converting the various concentrations to the discussed compounds. Analysis for phenols, total alkalinity and chromium were performed on selected samples. These analyses were also made on Citico Creek, near its confluence with Nickajack Reservoir. On Friar Branch, South Chickamauga Creek, and Nickajack Lake, bacterial analyses were performed at several selected stations. These included total and fecal coliform densities and Azotobacter and Pseudomonas.

Nickajack Lake

Four sampling transects were established in Nickajack Lake on which three sampling points (middle and quarter points) were selected. At each of these twelve stations a sample was taken at the surface and at a depth of about 10 feet. Parameters immediately measured included temperature, pH and dissolved oxygen. Samples were analyzed for nitrogen series, COD and total organic carbon in a field laboratory. These locations are also shown on FIGURE 4.

Chattanooga Water Plant

Raw water samples were taken around-the-clock at two-hour intervals from the Chattanooga Water Plant for pH and nitrogen series data.

DYE TRACER STUDY

Approximately 10 gallons of Rhodamine WT dye were added to the FCA discharge in order to evaluate dilution characteristics and to determine time of travel from the outfall to the water plant. A continuous monitoring device was operated at specific locations along the travel route between these points to show arrival time, diffusion characteristics and peak concentration. After the dye entered Nickajack

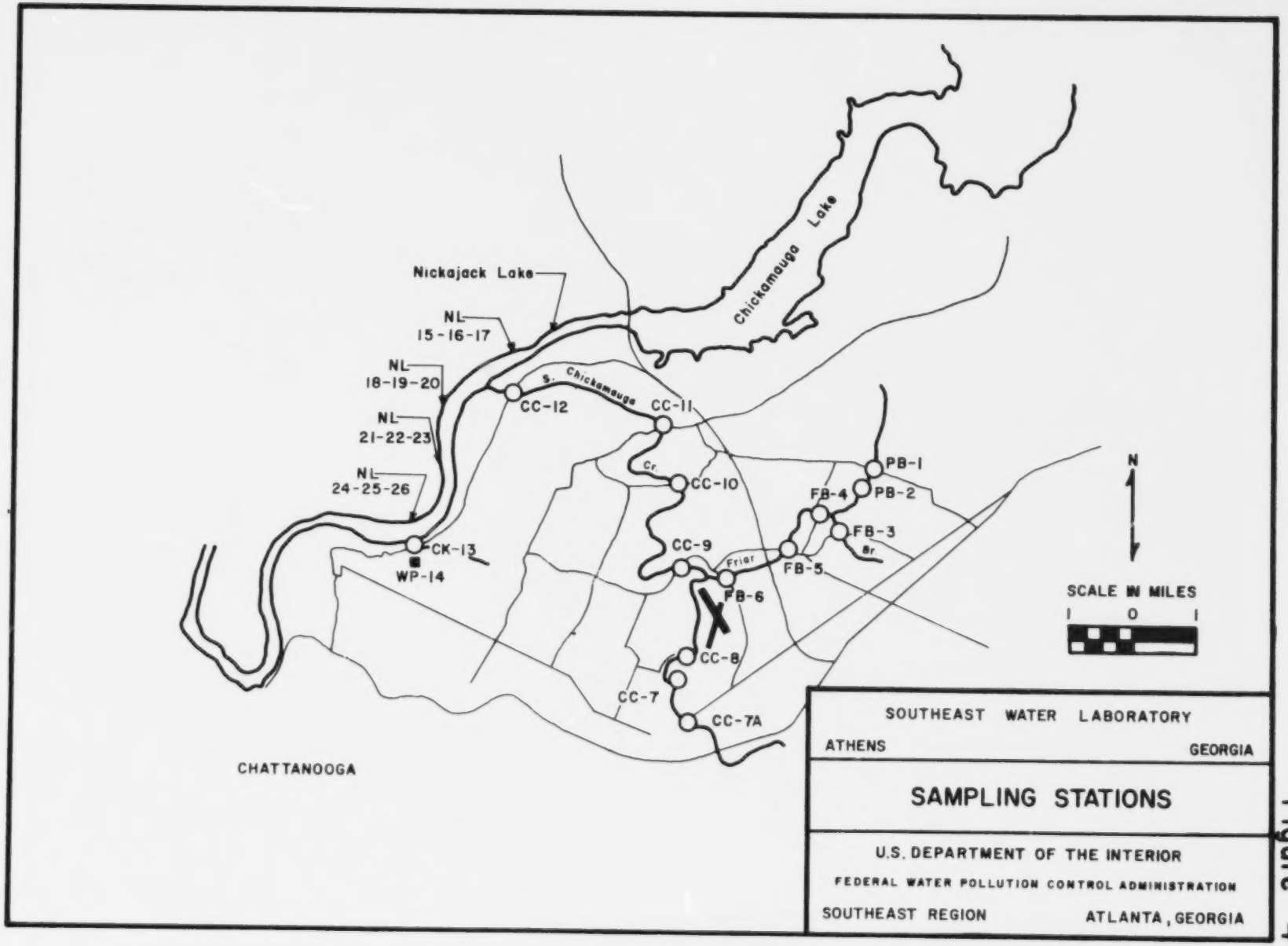

Nickajack Lake
NL
15-16-17
NL
18-19-20
NL
21-22-23
NL
24-25-26
Chickamauga Lake
S. Chickamauga Cr
CC-12
CC-11
CC-10
CC-9
CC-8
CC-7
CC-7A
CK-13
WP-14
PB-1
PB-2
FB-4
FB-3
FB-5
FB-6
Friar Br
CHATTANOOGA
N
SCALE IN MILES
1 0 1
SOUTHEAST WATER LABORATORY
ATHENS GEORGIA
SAMPLING STATIONS
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTHEAST REGION ATLANTA, GEORGIA

Figure 4

Lake, the sampling transects previously discussed were used to evaluate dispersion in the reservoir. Dye samples were collected from the water plant intake for time of passage and dilution calculations.

BIOLOGICAL STUDY

Benthos

Bottom-dwelling invertebrates were collected from riffle areas that transected South Chickamauga Creek near Stations CC-8 and CC-9. A square-foot stream bottom sampler (Surber sampler) was used to quantitatively collect benthos. The invertebrates were transferred from the sampler net into wide mouth jars and preserved with 5 percent formalin. These jars were returned to the Southeast Water Laboratory, Athens, Georgia, where organisms were separated, identified and counted.

Bioassay

A 96-hour insitu bioassay was conducted at Stations CC-8 through CC-12 in South Chickamauga Creek and at Stations FB-3, FB-5 and FB-6 in Friar Branch. Fish cages were made from barbeque baskets lined with 1/16 inch mesh nylon netting to prevent the escape of the test fish, fathead minnows (Pimephales promelas Raf.). Cages were attached to floats and anchored at a 2-foot depth in midstream. Ten fathead minnows were placed in each cage to facilitate calculation of the percentage of survival. Cages were examined and dead test fish were removed at 24-hour intervals. A record of the percentage of fish survival was made during each 24-hour examination.

A description of sampling stations is given in TABLE II.

TABLE II

DESCRIPTION OF SAMPLING STATIONS

FCA-1	Drainage ditch, approximately 200 feet southeast of the FCA nitric acid plant, at the gauging wier.
FCA-2	Drainage ditch, approximately 100 feet south of the FCA anhydrous ammonia plant.
FCA-3	Drainage ditch, approximately 50 feet downstream of the confluence of the two streams described above (FCA-1 & -2) on the east side of the main access road.
FCA-4a	Access manhole leading to a submerged sewer in front of the FCA ammonia nitrate plant.
FCA-4b	Drainage ditch, between the FCA urea and ammonium plants, about 100 feet west of the East Acid Road.
FCA-4	Drainage ditch approximately 50 feet downstream of the confluence of the two streams described above (FCA 4a and 4b) on the east side of East Acid Road, at the gauging wier.
FCA-5	Main FCA drainage about 100 feet east of the main access road at about 600 feet north of its intersection with East Acid Road.
FCA-6	Main FCA drainage ditch at the intersection of East Acid Road and the main access road at the gauging wier.
FCA-7	FCA sewage treatment plant effluent south of the railway crossing.
FCA-7a	FCA access manhole leading to the FCA sewage treatment plant bypass sewer.
FCA-8	Discharge gate to FCA number one holding pond, north of Rt. 2A.

CONT'D.

TABLE II CONT'D.

Description of Sampling Stations

PB-2 Discharge point from FCA number two holding pond into creek, south of Rt. 2A.

FB-3 Friar Branch at the Standifer Gap Road highway crossing.

FB-4 Friar Branch at the Reid Road highway crossing.

FB-5 Friar Branch at the Shallowford Road highway crossing.

FB-6 Friar Branch at the Airport Road highway crossing.

CC-7a S. Chickamauga Creek at the Lee Highway crossing.

CC-7 S. Chickamauga Creek, about 500 feet upstream of the Brainerd sewage treatment plant.

CC-8 S. Chickamauga Creek, about 1000 feet downstream of the Brainerd sewage treatment plant.

CC-9 S. Chickamauga Creek, at the Shallowford Road crossing.

CC-10 S. Chickamauga Creek at the Lightfoot Mill Road crossing.

CC-11 S. Chickamauga Creek at the Highway 58 crossing.

CC-12 S. Chickamauga Creek at the Amnicola Highway crossing.

CK-13 Citico Creek at the Amnicola Highway crossing.

NK-15-26 Sampling stations across Nickajack Lake, three per transcet as follows: NK-15-17 approximately 500 feet upstream of the S. Chickamauga Creek confluence at river mile 468.3, NK-18-20 approximately 0.5 miles below the S. Chickamauga Creek confluence at river mile 467.7, NK-21-23 approximately 1.5 miles below the S. Chickamauga Creek confluence at river mile 466.7,

CONT'D.

TABLE II CONT'D.

Description of Sampling Stations

NK-24-26 approximately 2.5 miles below the S.Chickamauga Creek confluence and about 1000 feet above the Chattanooga Water Company intake structure.

VIII. EFFECTS OF POLLUTION

HYDROLOGY

Flows measured at the discharge point of Farmers Chemical Association averaged 0.76 cubic feet per second (cfs) (0.5 mgd) for the three-day test period. However, this average is biased by a low value of 0.24 cfs observed on one of the sampling days due to holding following an acid spill. Normally, the discharge approximates 1 cfs or 0.65 mgd. After leaving the outfall, the average rate of flow was 0.10 miles per hour until the confluence with Friar Branch. The volume of flow in Friar Branch was measured at 5.4 cfs during the survey. Friar Branch affords a five-fold dilution to the FCA waste under base flow conditions. Friar Branch flows 2.5 miles from the confluence with FCA waste until it joins South Chickamauga Creek at river mile 9.2. Time of travel of dye dumped at the FCA outfall measured to the confluence with South Chickamauge Creek was approximately 14 hours. The flow in South Chickamauga Creek was considerably below the reported average flow rate. Gauging Station 3-5675.00 of the U. S. Geological Survey located upstream from the Friar Branch confluence, indicated an average flow of 137 cfs as compared to an average annual thirty-two year flow record of 682 cfs. Therefore, the dilution afforded Friar Branch by South Chickamauga Creek approximated 25 to 1 with an overall expected dilution of FCA waste calculated at about 140. Flow in South Chickamauga Creek between river mile 9.2 and the mouth was estimated to be 146 cfs. Total distance of travel between the FCA outfall and the mouth of South Chickamauga Creek is 11.9 miles with an average velocity of 0.17 mph. Under survey conditions, a travel time of 68 hours was observed between the time of

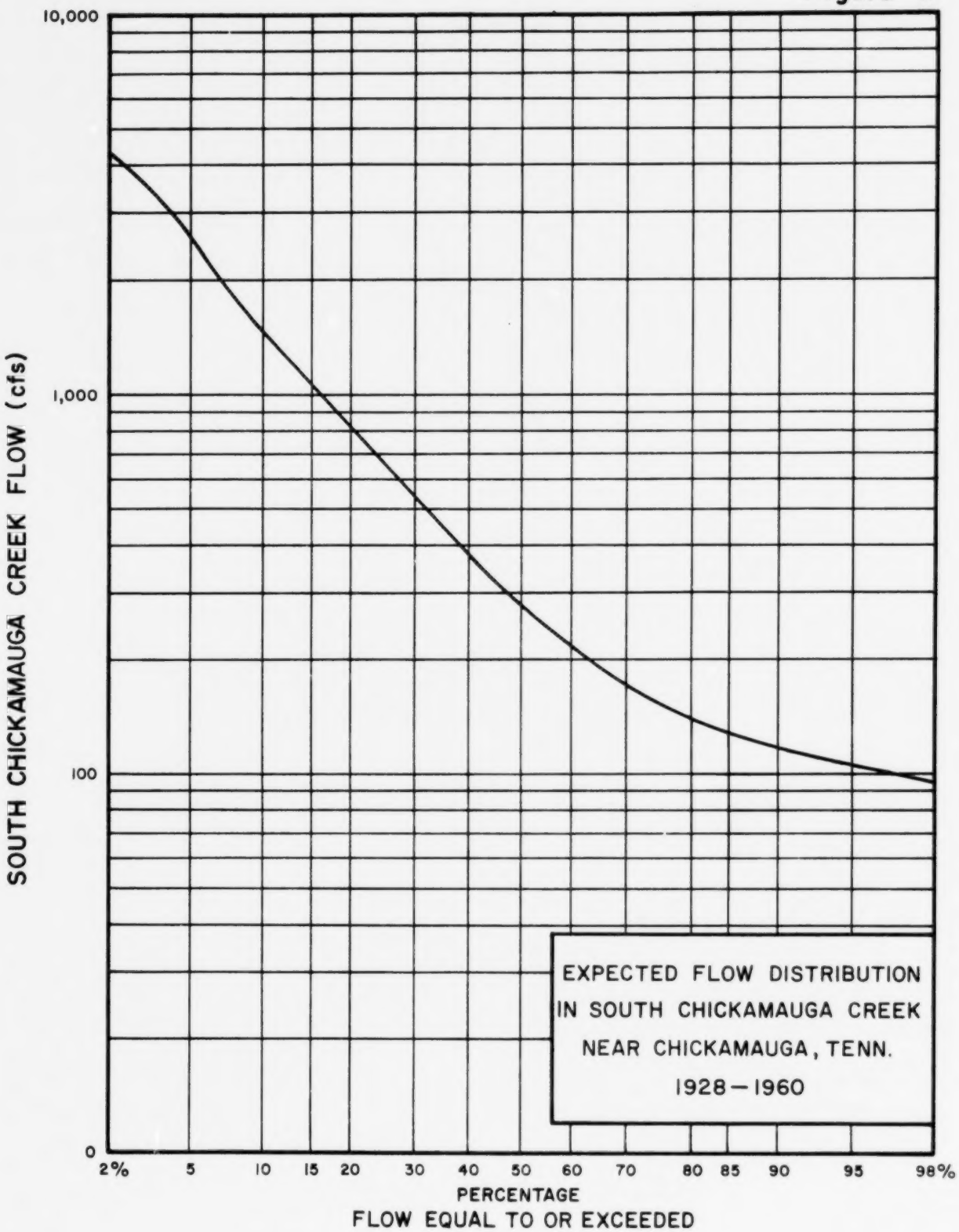
release of dye at the Farmers Plant and time of its entry into Nickajack Lake.

Data compiled over the past 32 years, on South Chickamauga Creek has shown a variation in average daily flow from 98 cfs to 4,400 cfs. Assuming a base flow of 5.4 cfs from Friar Branch, this would represent a variation in dilution of Friar Branch by South Chickamauga Creek of a minimum of 18 to a maximum of over 800 with an average dilution of about 90. This indicates that ammonia concentrations at the mouth of South Chickamauga Creek could vary over 40 fold assuming the amount of ammonia in all waste effluents remain constant. However, at least 95% of the time, dilution can be expected to account for a minimum reduction of 20 times in South Chickamauga Creek in ammonia concentrations from Friar Branch. The expected flow distribution in South Chickamauga Creek is shown in FIGURE 5.

It is possible that high flows in South Chickamauga Creek could prove a disadvantage under other circumstances. A small but significant reduction in waste concentrations was observed as a function of downstream travel. Higher flows will reduce the time of travel and reduce the amount of assimilation which might be anticipated. A second influence of high flows would be an increase in volume of water from this source entering Nicka ack Lake. The greater volume of more highly contaminated water from South Chickamauga Creek could result in a higher degree of contamination in the lake.

Flow in Nickajack Lake is recorded at the U. S. Geological Survey gauging station (3-5680.00) below the entry point of South Chickamauga Creek. During the survey period average daily flows measured at the station varied from 27,300 to 32,200 cfs. Release at Chickamauga Dam

Figure 5


10,000
1,000
100
0
SOUTH CHICKAMAUGA CREEK FLOW (cfs)
2%
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
PERCENTAGE
FLOW EQUAL TO OR EXCEEDED
EXPECTED FLOW DISTRIBUTION
IN SOUTH CHICKAMAUGA CREEK
NEAR CHICKAMAUGA, TENN.
1928—1960

was fairly stable with a minimum 4-hour discharge rate of 26,500 cfs. Flows of this magnitude were considerably above discharges recorded during the latter part of the month of September when operating difficulties were encountered at the Chattanooga water plant. Average daily flows ranged from 7,450 to 21,000 cfs for the period for September 10-30, 1968, with an overall average of about 13,000 cfs discharge. Four-hour discharge rates during night hours in this period were often recorded as zero. Due to the high flow rate during the survey period, the tracer dye, released at FCA entered the Nickajack impoundment and was diluted to a concentration below detectable limits. Consequently, it was impossible to identify the dispersion characteristics of flows entering Nickajack Lake from South Chickamauga Creek. The survey period did not represent a critical demand period at the water plant.

WATER QUALITY

FCA

Of the five point sources sampled within the FCA plant, the one shown to be the highest contributor of ammonia was the anhydrous ammonia plant. Wastes from this operation were collected at sampling point FCA-1. Its discharge of approximately 0.7 cfs contained an average of 113 mg/l ammonia for a total NH_3 output of 428 pounds/day. This represented 43% of the average total of 1,000 lbs/day of ammonia discharged during the survey period. Ammonia concentrations from the acid area averaged 233 mg/l amounting to a total waste discharge of 227 pounds/day. The urea and nitrate operations showed very high concentrations of 1095 and 680 mg/l respectively with a combined total discharge of 314 pounds per day.

The nitrite-nitrate waste originating in the acid area was detected in samples taken from FCA-2. At a concentration of 348 mg/1, nearly 340 pounds per day were discharged in this drainage ditch. Samples taken from FCA-4a and 4-b ditches flowing from the urea and nitrate plants showed extremely high concentrations of nitrites and nitrates averaging 1085 mg/1 and 627 mg/1 respectively. With a combined average flow of only 0.06 cfs (FCA-4) from these two sources, 385 pounds of NO_2-NO_3 were wasted each day. The anhydrous ammonia production showed 55 mg/1 of nitrite-nitrate waste for a total waste load of 200 pounds per day. Total nitrite-nitrate output during this period for the plant was 1260 pounds per day (FCA-8).

The urea and nitrate plants exhibited an average total Kjeldahl nitrogen concentration of 1068 mg/1 for an organic nitrogen waste quantity of 346 pounds per day. The anhydrous ammonia operation discharged 452 pounds per day and the acid area discharged 237 pounds per day. Total Kjeldahl nitrogen (nitrogen plus ammonia) output for the plant was recorded as 1450 pounds per day.

Total chemical oxygen demand was measured at 18.3 mg/1 at the outfall at the plant. Bacterial analysis showed an extremely high coliform density at the FCA outfall. An average of nearly 100,000 organisms per 100 ml (MPN) were detected at this location.

During one of the three sampling days, only 0.24 cfs of waste was discharged from FCA. If this unrepresentative low discharge is eliminated, the average waste flow from FCA approximates 1 cfs. At this flow, which is thought to more realistically reflect FCA's total discharge, the waste quantities of ammonia, nitrite-nitrate and organic nitrogen are 1315 pounds per day, 1660 pounds per day and 1915 pounds per day respectively.

TABLE III

MEAN WATER QUALITY-FARMERS CHEMICAL ASSOCIATION

October 15-17, 1968

Station	Flow Rate cfs	Temp. °C	Ph	DO (mg/1)	NH_3-N (mg/1)	$(NO_2$-$NO_3)$-N (mg/1)	Kjeldahl N (mg/1)	COD (mg/1)	TOC (mg/1)	TIOC (mg/1)	Phenols ppb	Alk. ppm
FCA-1	0.67	34.5	7.9		113	55.0	125					
-2	0.18	34.3	8.6		233	348	244					
-3	0.85	36.3	8.4		103	127	133					
-4	0.06	38.0	5.0		976	1188	1068					
-4a		49.4	4.5		1095	1085	1184					
-4b		52.5	7.6		680	627	698					
-5		31.3	5.7		230	275	246					
-6	0.82	29.3	5.7		223	277	233					
-7	0.11	22.5	3.6		7.4	19.4	9.6					
-7a		23.8	4.2		21.4	23.2	38.5					
-8	0.76	23.3	7.6		243	307	354	18.32	5	3		

Data collected at FCA are listed in TABLE III. Individual values are tabulated in the data appendix.

A survey of the contaminants contained in the waste discharge from FCA in support of the TNT production was performed. Samples were taken from the aeration basin near the acid area of the plant utilizing an automatic sampling device. Analysis of the 20 mgd flow showed concentrations to vary from less than 0.01 mg/l to 0.7 mg/l ammonia with an average of approximately 0.4 mg/l. Concentrations appeared to vary with time of sampling with a high peak discharge existing at 2:00 PM, and low peak at 10:00 AM during the test period. Waste from this source is directed north and into Waconda Bay, rather than into South Chickamauga Creek.

Friar Branch

These data are shown in FIGURES 6 and 7 and listed in TABLE IV. Background analysis of Friar Branch, upstream from the confluence with the FCA waste showed a very low background level of ammonia, NO_2-NO_3 and total Kjeldahl nitrogen. These levels increased appreciably with the addition of the FCA waste. Ammonia concentrations increased from 0.8 to 91.0 mg/l, nitrate-nitrite from 4.1 to 108 mg/l and total Kjeldahl nitrogen from 1.1 to 93.2 mg/l. Below the confluence total organic carbon (TOC) increased from 3 to 8 mg/l and total inorganic carbon (TIOC) increased from 1 to 6 mg/l. Chemical oxygen demand (COD) values increased in Friar Branch from 7.16 to 9.42 mg/l below the FCA waste confluence.

A significant increase in COD and total inorganic carbon, accompanied by smaller increases in organic carbon and ammonis, was observed at FB-6. The COD showed an increase of over five times chemical oxygen demand at FB-6 above that at FB-5 (COD at FB-5: 9.0 mg/l; COD at FB-6: 47.9 mg/l).

Figure 6

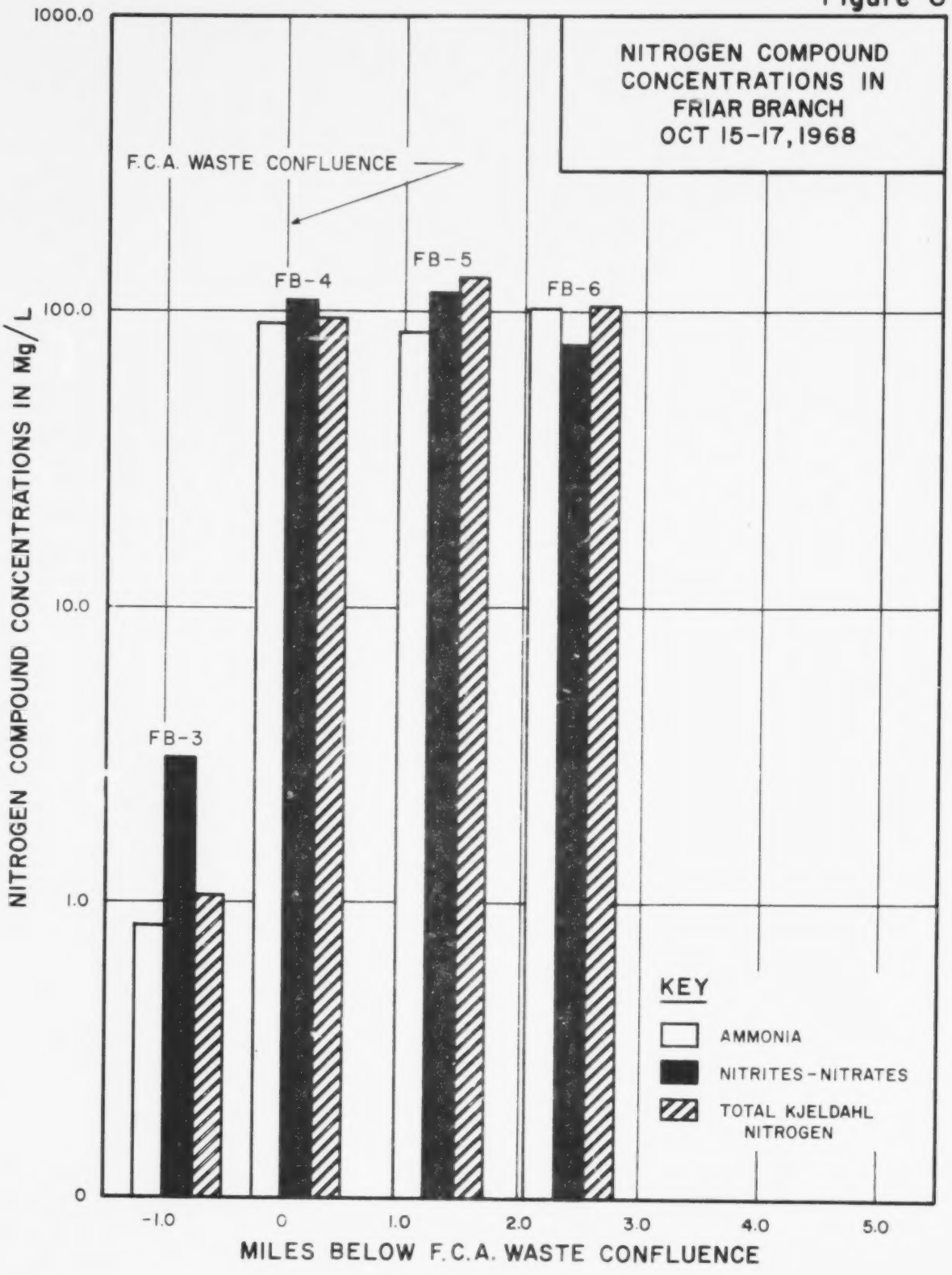
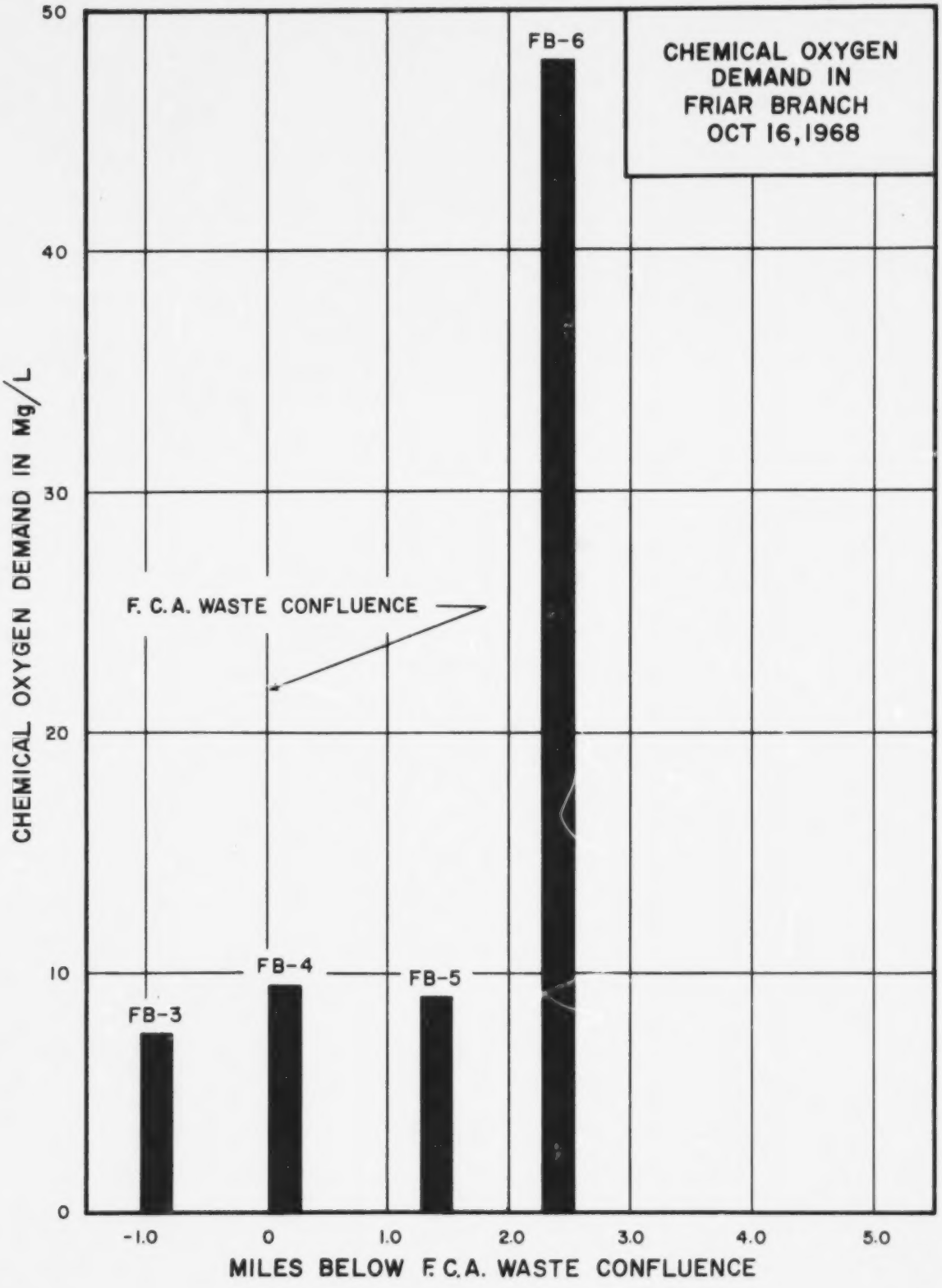

NITROGEN COMPOUND CONCENTRATIONS IN FRIAR BRANCH OCT 15-17, 1968
F.C.A. WASTE CONFLUENCE
FB-3
FB-4
FB-5
FB-6
1000.0
100.0
10.0
1.0
0
NITROGEN COMPOUND CONCENTRATIONS IN Mg/L
KEY
AMMONIA
NITRITES-NITRATES
TOTAL KJELDAHL NITROGEN
-1.0
0
1.0
2.0
3.0
4.0
5.0
MILES BELOW F.C.A. WASTE CONFLUENCE

Figure 7


CHEMICAL OXYGEN DEMAND IN FRIAR BRANCH OCT 16, 1968
CHEMICAL OXYGEN DEMAND IN Mg/L
50
40
30
20
10
0
F. C. A. WASTE CONFLUENCE
FB-3
FB-4
FB-5
FB-6
-1.0
0
1.0
2.0
3.0
4.0
5.0
MILES BELOW F. C. A. WASTE CONFLUENCE

Ammonia concentration increased about 18% from 85 mg/l to 100 mg/l. Analysis for total alkalinity as $CaCO_3$ exhibited the highest of any station surveyed, at 227 mg/l for two days tests, and phenols were also high at this location showing 10 ppb. Two firms known to discharge industrial waste in this reach of the stream are Southeast Polymer and Burkhart-Schier Chemical Companies which are now owned by General Aniline and Film Corporation. Although direct measurement of the volume and character of the discharge from Southeast Polymer and Burkhart-Schier Companies were not made, mass balance computations indicate that approximately 2.1 mgd (3.3 cfs) of waste was discharged collectively by these sources during the survey. In this effluent, an estimated 1970 pounds ammonia is discharged to Friar Branch each day. It is suggested that a comprehensive investigation of the quantity and composition of waste generated by these two installations be conducted by the Tennessee Division of Stream Pollution Control. Immediately downstream of FB-6 Friar Branch joins South Chickamauga Creek.

South Chickamauga Creek

These data are plotted in FIGURES 8 and 9 and listed in TABLE IV. Background concentrations in South Chickamauga Creek at CC-7 and CC-7a indicated relatively low levels of compounds in the nitrogen series. Ammonia averaged 0.28 and 0.70 mg/l at these two points respectively; nitrite-nitrate concentrations were 0.29 and 0.70 mg/l. Levels were generally higher at CC-7a owing to the effluent from the East Ridge sewage treatment plant and generally tended to decrease downstream. The excessive level of total Kjeldahl nitrogen (16.4 mg/l) presents an anomaly for which no apparent cause was found.

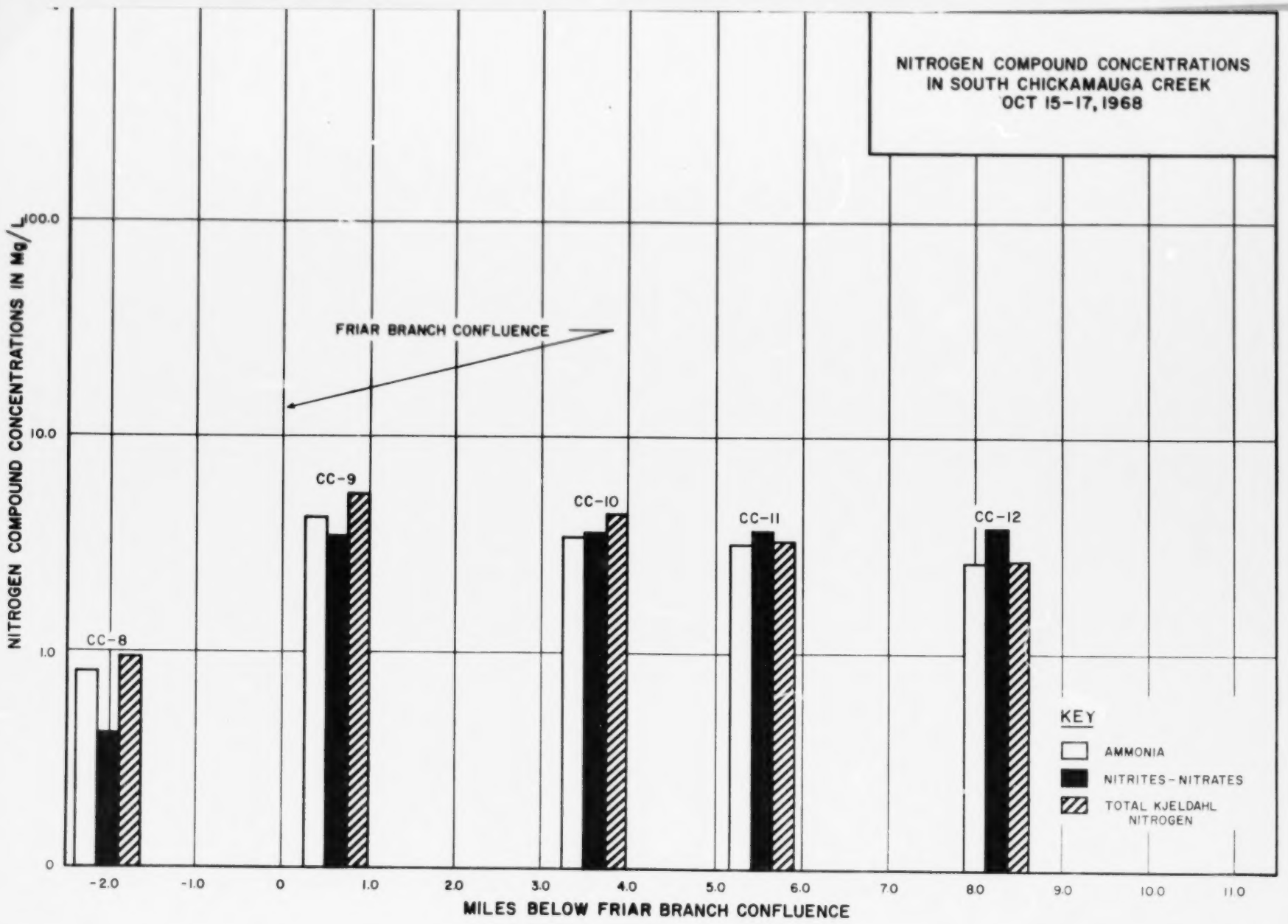

NITROGEN COMPOUND CONCENTRATIONS
IN SOUTH CHICKAMAUGA CREEK
OCT 15-17, 1968
NITROGEN COMPOUND CONCENTRATIONS IN Mg/L
100.0
10.0
1.0
0
FRIAR BRANCH CONFLUENCE
CC-8
CC-9
CC-10
CC-11
CC-12
KEY
AMMONIA
NITRITES-NITRATES
TOTAL KJELDAHL NITROGEN
-2.0
-1.0
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
MILES BELOW FRIAR BRANCH CONFLUENCE

Figure 9

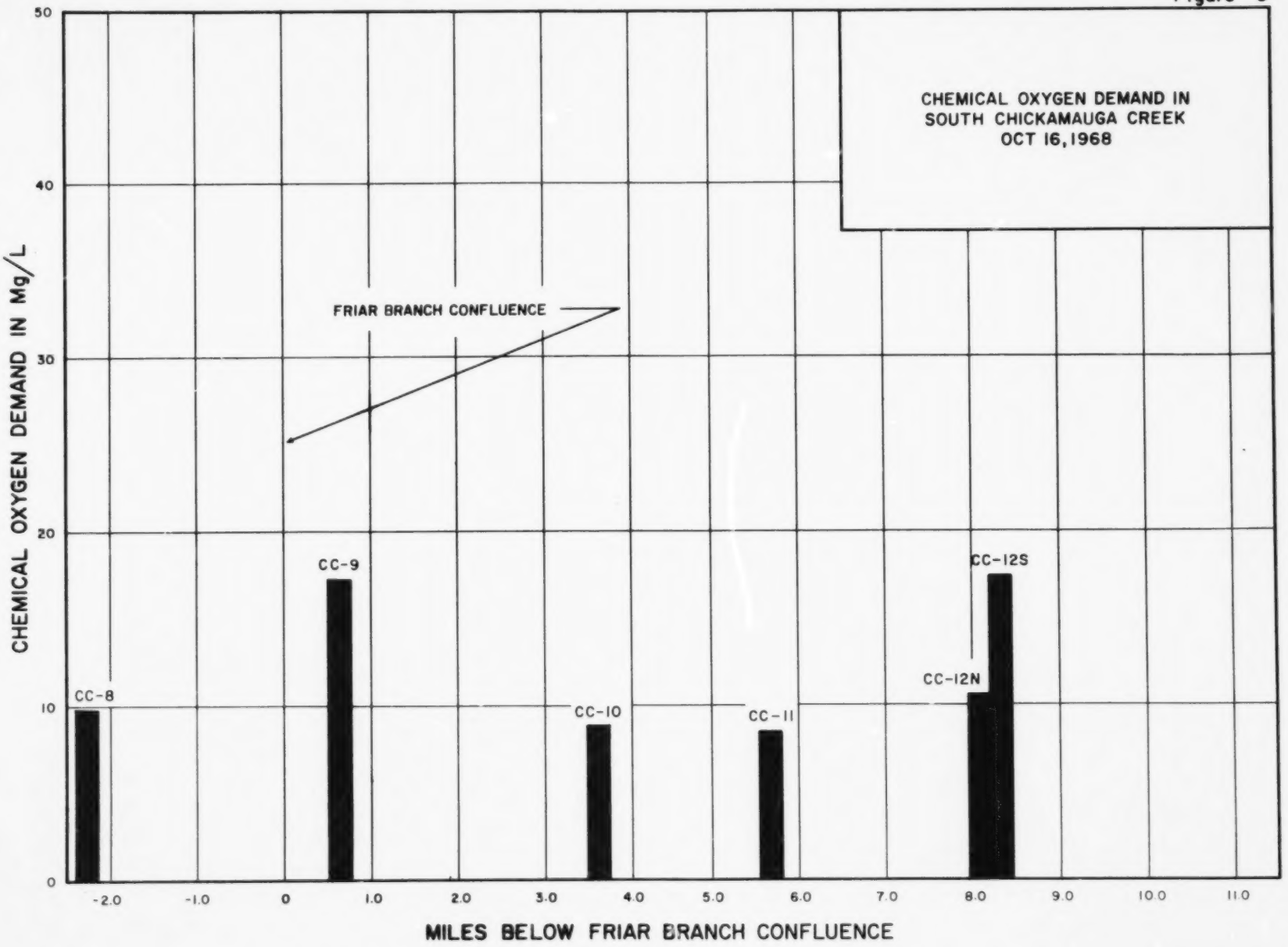

CHEMICAL OXYGEN DEMAND IN
SOUTH CHICKAMAUGA CREEK
OCT 16, 1968
FRIAR BRANCH CONFLUENCE
CHEMICAL OXYGEN DEMAND IN Mg/L
50
40
30
20
10
0
CC-8
CC-9
CC-10
CC-11
CC-12N
CC-12S
-2.0
-1.0
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
MILES BELOW FRIAR BRANCH CONFLUENCE

TABLE IV

MEAN WATER QUALITY-FRIAR BRANCH, SOUTH CHICKAMAUGA CREEK, CITICO CREEK

October 15-17, 1968

Station	Flow Rate cfs	Temp. °C	Ph	DO (mg/l)	NH_3-N (mg/l)	(NO_2-NO_3)-N (mg/l)	Kjeldahl N (mg/l)	COD (mg/l)	TOC (mg/l)	TIOC (mg/l)	Phenols ppb	Alk. ppm
PB-2		23.8	7.6		246	277	350				5	70
FB-3		18.4	7.3		0.80	4.1	1.1	7.16	3	1		
-4		19.6	7.2		91	108	93.2	9.42	8	6		
-5		20.4	7.3		85	113	128	9.00	4	1		
-6	5.4	21.7	8.6		100	74	102	47.93	14	2	10	227
CC-7a		19.8	7.3	5.0	0.70	0.70	16.4					
-7	137	19.8	7.3	4.7	0.28	0.29	1.15					
-8		20.0	7.4	5.1	0.80	0.41	0.92	9.74	10	9	6	138
-9	142	20.8	7.7	4.3	4.3	3.5	5.10	17.25	8	1	7.5	138
-10		19.8	7.4	4.7	3.5	3.6	4.40	8.81	4	1		
-11		20.2	7.8	5.4	2 2.2	4.9	2.38	8.44	11	11	10	135
-12N		20.8	7.7	3.6	2.6	4.1	3.23	10.53	4	1	6	142
-12S		20.7	7.7	3.3	2.6	3.6	3.53	17.33	8	1	7	139
CK-13		22.3	7.6	0.1	3.8	0.04	4.89	58.02	20	1	30	163

Analysis of coliform density revealed a high level of both total and fecal coliform at 96,500/100 ml and 8,600/100 ml respectively at CC-7. The origin of this bacterial contamination was probably the East Ridge plant and the inadequate systems at Ringgold and Fort Oglethorpe as well as other areas in Georgia served only by septic tanks, all of which discharge or drain to South Chickamauga Creek. Effluent from the Brainerd sewage treatment plant enters just below CC-7 and the increase in waste load is shown in the higher ammonia levels at Station CC-8. The Brainerd sewage treatment plant contributes 390 lbs/day of ammonia.

Friar Branch joins South Chickamauga Creek between CC-8 and CC-9. An immediate increase in ammonia (0.8 to 4.3 mg/1), nitrites and nitrates (0.4 to 3.5 mg/1), total kjeldahl nitrogen (0.9 to 5.1 mg/1) and COD (9.7 to 17.3 mg/1) occurs at CC-9.

The five mile stretch of South Chickamauga Creek between CC-9 and CC-11 is sparsely populated and the chemical contaminants show a consistent decline as a function of downstream distance. Nitrite-nitrate concentrations increased as assimilation of the unsatisfied nitrogen compounds proceeded. An increase in total organic and inorganic carbon suggests a waste source between Lightfoot Mill Road and Highway 58. This source was not identified in this study.

Analyses at Station CC-12 were performed at two locations on both sides of the creek at quarter points. Separate analyses were performed at this station since a dark murky discharge was observed flowing along the southern shore, apparently from a waste source located just upstream from the station. Companies discharging waste in this section include Davidson Chemical, Ray-Ser Dyeing, Mueller, Special Products, and Alco Companies. Nitrogen series evaluations showed a decrease on both sides

of the channel with nitrite-nitrate analysis showing a small increase. Ammonia levels at this point averaged 2.6 mg/l and were uniformly distributed across the channel cross section. Total Kjeldahl nitrogen averaged 3.4 mg/l and were also relatively uniform through the cross section compared to 2.4 mg/l at CC-11. The increase of the COD, particularly on the southern side further suggested the influence of sources of carbonaceous waste between stations CC-11 and CC-12. The COD on the south side of the channel was measured at 17.3 mg/l, while the level on the north side was only 10.5 mg/l. Total organic carbon, although decreased from Station CC-11, was twice as high on the south side of the stream as on the north. Dissolved oxygen was also less on the south side (3.3 mg/l on south and 3.6 mg/l on north) and was significantly reduced from that at Station CC-11 (5.4 mg/l at CC-11). A slight increase in alkalinity was also measured at this point. Bacterial analysis indicated a further reduction of coliform density at CC-12 below all previous upstream stations. However, total coliform densities on the south side of the creek were over forty times greater than total coliform density than the north side although fecal concentrations were lower. Coliform data for the area are shown in TABLE VI at the end of this section.

Nickajack Lake

Ammonia, nitrite-nitrate and total Kjeldahl nitrogen concentrations measured at transects across the impoundment, all dropped significantly after entering Nickajack Lake from South Chickamauga Creek. Average ammonia concentrations above the confluence were 0.06 mg/l. Below the confluence, ammonia averaged 0.08 mg/l, an increase of 33%. Although samples were taken at quarter points across the river at surface and

mid-depth, no trend which would indicate stratification could be identified. High ammonia levels were detected at different locations during each day's survey and average figures indicated no clear indication of channeling to exist. Ammonia and total Kjeldahl nitrogen concentrations at the transect near the Chattanooga water plant intake averaged about 0.10 mg/l and 0.42 mg/l respectively with the COD indicating 18.5 mg/l. There is a three-fold increase in COD from the next upstream transect but no corollary increase in total organic and inorganic carbon. The COD above the confluence averaged 5.8 mg/l. These values are listed in TABLE V.

Citico Creek

Analysis performed near the mouth of Citico Creek indicated that the water flowing into Nickajack Lake is of a poor quality. Ammonia and total Kjeldahl nitrogen showed higher concentrations of these contaminants to exist at the mouth of Citico Creek than at the mouth of South Chickamauga Creek. For the three-day period, ammonia concentrations at the mouth of South Chickamauga Creek averaged 2.6 mg/l while average ammonia levels of 3.8 mg/l were measured at Citico Creek. Relatively high levels of phenols (30 ppb) and alkalinity (163 mg/l) were also measured at this location. Dissolved oxygen levels were 0.0 mg/l for two of the three sampling days, and 0.2 mg/l on the third day. This lack of oxygen can be attributed to an oxygen demand indicated by the high chemical oxygen demand of 58.0 mg/l measured on the first day's analysis. Organic carbon was also excessively high at 20 mg/l. The major contributor identified in this area is Southern Railroad Yards. Discharge of waste diesel fuel could account for the unusually high levels of organic carbons and phenols observed.

TABLE V

MEAN WATER QUALITY-NICKAJACK LAKE

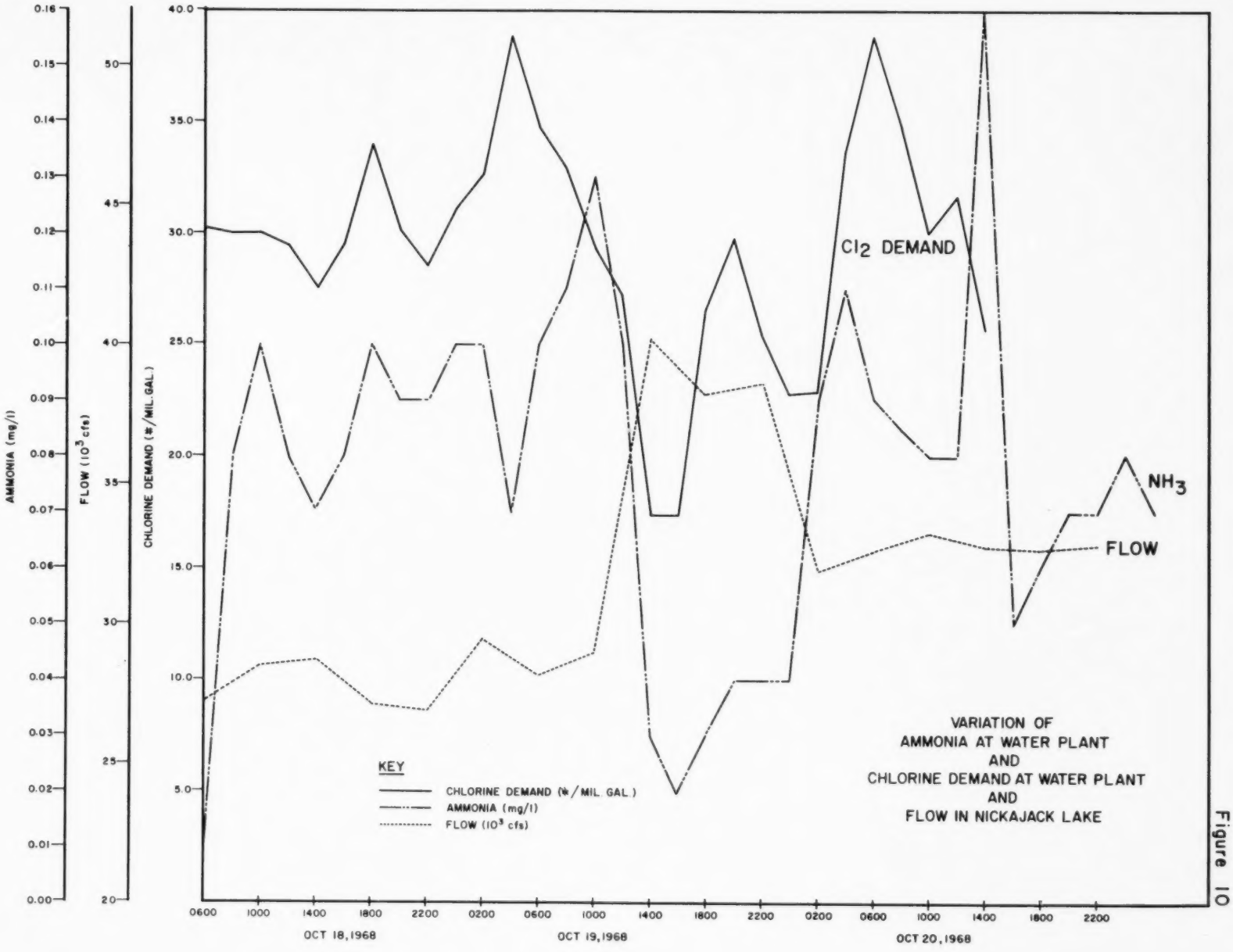
October 18-21, 1968

Station	Flow Rate cfs	Temp. °C	Ph	DO (mg/1)	NH_3-N (mg/1)	(NO_2-NO_3)-N (mg/1)	Kjeldahl N (mg/1)	COD (mg/1)	TOC (mg/1)	TIOC (mg/1)	Phenols ppb	Alk. ppm
15-16-17*		20	7.4	6.2	0.06	0.39	0.43	5.75	3	1		
18-19-20		20	7.5	6.3	0.08	0.39	0.31	9.15	3	1		
21-22-23		20	7.5	6.3	0.09	0.39	0.33	6.57	2	1		
24-25-26		20	7.6	6.2	0.10	0.42	0.42	18.49	3	1	5	62

*Data based upon average values of analyses performed at three lateral points, at the surface and at a depth of 10 feet on days 18, 20 and 21.

Chattanooga Water Plant

Ammonia, nitrite-nitrate and total Kjeldahl nitrogen analysis were performed on the raw water supply at the Chattanooga water plant for a three-day period at 2-hour intervals. Ammonia concentrations ranged from less than 0.01 mg/l to 0.16 mg/l during the sampling period (FIGURE 10). The distribution showed a low level from October 15 until 6:00 am October 18, increasing abruptly at 8:00 am on the 18th and remaining so until a peak of 0.13 mg/l was reached at 10:00 am on the 19th. By 4:00 pm on the 19th the ammonia concentration had declined to 0.02 mg/l and remained fairly low until the following morning where a second peak 0.11 was reached at 4:00 am on the 20th. Concentrations remained in the moderate range for the remainder of the testing period. During this period there appeared to be good correlation between ammonia concentration and river flow regime as well as a clear indication that ammonia concentration and chlorine demand at the water plant were related. Bacteriological analysis indicated that raw water supplies contain a significant coliform population. The two-day evaluation showed an average of 3100/100 ml total coliform and an average of 60 colonies/100 ml were of fecal origin. It should be noted that although this degree of bacterial contamination does not exceed standards for domestic raw water supply, the total coliform levels are high andmay reflect the influence of industrial waste discharges upon the water supply. Finished water samples showed coliform densities were absent or below detectable limits. Samples of both raw and finished water were analyzed for the presence of the groups Pseudomonas and Azotobacter. All analyses were found negative for these organisms.



VARIATION OF
AMMONIA AT WATER PLANT
AND
CHLORINE DEMAND AT WATER PLANT
AND
FLOW IN NICKAJACK LAKE

Figure 10

TABLE VI

BACTERIOLOGICAL DATA

South Chickamauga Creek and Vicinity
October 1969

TOTAL AND FECAL COLIFORM DENSITIES

STATION(1)	10/18/68		10/21/68	
	TOTALS MPN/100ml.	FECALS MPN/100ml.	TOTALS MPN/100ml.	FECALS MPN/100ml.
WTP(FIN)	2	2	2	2
WTP(RAW)	4900	70	1300	49
NK-16	4900	20	1700	2
NK-25	2300	20	3300	5
PB-1	**	**	2	2
PB-2	160,000	50	**	**
CC-7	160,00	17,000	33,000	200
CC-9	24,000	310	35,000	460
CC-12N	300	80	**	**
CC-12S	13,000	60	13,000	330

** = No Sample

(1)Species of pseudomonas were detected at Stations NK-25, CC-7 and CC-9 on both sampling dates. Failure to detect members of the group at the remaining stations does not imply their complete absence. Species of proteus were demonstrated in the WP-raw and CC-9 samples. Treated water samples produced no evidence of azotobacters or pseudomonads.

BIOLOGY

An insitu bioassay test was performed in which live flathead minnows were caged at various locations of Friar Branch and South Chickamauga Creek. This procedure showed very graphically the result of waste discharges upon aquatic life (FIGURE 11). All test fish were killed within 48 hours at stations in Friar Branch below the confluence with the FCA waste discharge. Total mortality occurred more quickly at Station FB-6, just below the Southeast Polymer and Burkhart-Schier outfalls than above these outfalls at FB-5, where the fish were exposed only to the FCA waste. However, all of the segment of Friar Branch below the FCA waste confluence must be considered as toxic to aquatic life. In the upper reach of South Chickamauga Creek, just below the Friar Branch confluence only minor toxic effects were observed. Station CC-9, 0.5 mile below and CC-10, 3.5 miles below the confluence revealed 10% specimen mortality each in the 96-hour test. Ammonia concentrations during the study, measured in the range 3.0 to 5.0 mg/l, were considerably below the 8.2 mg/l level reported to represent the 96-hour TLM for flathead minnows.(8)

Toxic waste discharged by one or more of the firms located between river mile 2.1 and the mouth of South Chickamauga Creek resulted in 50% mortality of the test fish. Although ammonia levels were relatively low in this stretch, ammonia in combination with one or more chemicals can produce synergistic effects such as has been demonstrated between cyanides and ammonia. Ammonia is also reported to be more toxic under

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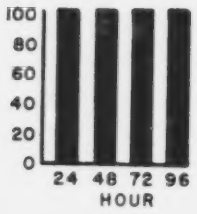
(8) Toxicity of 4,346 Chemicals to Larval Lampreys and Fishes, Applegate, Vernon C. and John H. Hawell, (Special Scientific Report-Fisheries No. 207), U. S. Dept. of the Interior, Fish and Wildlife Service, 1957.

Figure 11

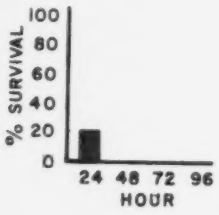
BIO-ASSAY RESULTS IN SOUTH CHICKAMAUGA CREEK TENNESSEE
OCTOBER, 1968



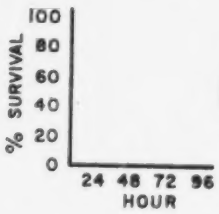
FB-3

F.C.A.

FRIAR BRANCH



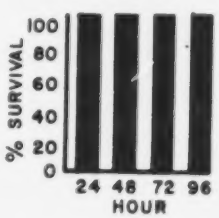
FB-5



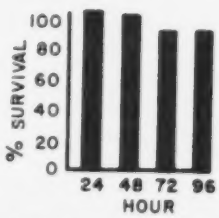
FB-6

NOTE: Each Histogram Shows the Percent of Test Fish, (Pimephales promelas Raf), Survival for 24, 48, 72, 96, Hour Exposure.

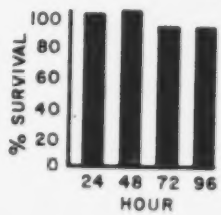
SOUTH CHICKAMAUGA CREEK



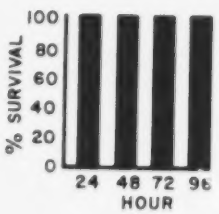
CC-8



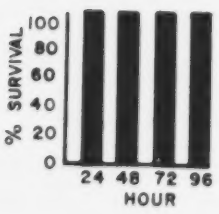
CC-9



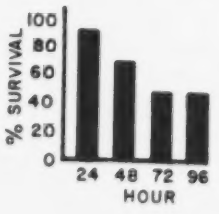
CC-10



CC-11



CC-12N



CC-12S

depressed oxygen and under high pH conditions as was observed in this reach.[9] Effluents may have been toxic in themselves as shown by the high alkalinity, color and COD observed at station CC-12S.

It should be noted that although test fish were able to survive for the full 96 hours of exposure at most points in South Chickamauga Creek this is not a clear indication that the delicate aquatic life cycle may not be adversely influenced as the result of the industrial waste at lower flows or higher temperatures.

Evaluation of benthic activity in Friar Branch and South Chickamauga Creek has shown a definite change in the total number and type of organisms living in certain areas influenced by waste from FCA. As illustrated by the McIntosh Diversity Index,[10] fewer organisms exist at CC-9, 0.5 miles below the Friar Branch confluence than at CC-8, 2.5 miles above the confluence. The effect of waste effluent on the benthic community does not generally appear to be serious in South Chickamauga Creek between mile 9.2 (Friar Branch) and mile 2.1. However, the study did reveal in localized areas a definite detrimental influence on the propogation of some forms of aquatic life in this area.

An ammonia concentration of 1.5 mg/l represents the maximum level in freshwater at which normal aquatic propagation can be maintained.[11]

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(9) Water Quality Criteria, State Water Pollution Control Board, Sacramento, California, Publication #3a, 1963.

(10) An Index of Diversity and the Relationship of Certain Concepts to Diversity, Robert P. McIntosh, Ecology 48(3); pp. 392-404, 1967.

(11) Detection and Measurement of Stream Pollution, M.M. Ellis, Bulletin of the Bureau of Fisheries, 48, 1937, (reprinted in Biology of Water Pollution, FWPCA, 1967).

This criterion is predicated on the fact that other chemicals are absent and that dissolved oxygen and pH are within acceptable limits. Since this study has shown an average of 0.8 mg/l ammonia to be present in South Chickamauga Creek just above the Friar Branch confluence, a concentration of 0.7 mg/l would represent the maximum increase allowable at the confluence during the survey period. Some moderate damage to the aquatic community in South Chickamauga Creek is taking place below the Friar Branch confluence. This degradation is the result of waste entering from Friar Branch and originating at FCA and from Southeast Polymer and Burkhart-Schier Company. The State of Tennessee has defined the three day-twenty year flow as the design discharge for establishing concentration limits in streams. For South Chickamauga Creek, this flow is 73 cfs. The maximum quantity of ammonia allowable to meet a criterion of 1.5 mg/l at this flow is 591 pounds per day. Above the confluence with Friar Branch, there is already 591 pounds per day of ammonia in South Chickamauga Creek. Therefore, if only FCA and G.A.F.'s Southeast Polymers-Burkhart-Schier effluents are considered for abatement of ammonia these discharges must attain 100% removal. This procedure is recommended in a long range abatement master plan for the Chattanooga area which would provide for the extension of the collection system to include all of the waste discharging to South Chickamauga Creek and Friar Branch. This would accomplish removal of all waste discharges from the drainage area.

However, at the present time, the Brainerd sewage treatment plant effluent above the confluence with Friar Branch contributes significant quantity of ammonia to South Chickamauga Creek. The estimated input of

ammonia to South Chickamauga Creek from all major sources is as follows: base concentration in South Chickamauga Creek is 200 pounds per day. Brainerd sewage treatment plant, 390 pounds per day; background concentration in Friar Branch, 60 pounds per day; Farmers Chemical Association, 1315 pounds per day and G.A.F.'s Southeast Polymers-Burkhart Schier, 1980 pounds per day; for a total of 3937 pounds per day. In order to reach an acceptable ammonia concentration of 1.5 mg/l in South Chickamauga Creek at the three day-twenty year flow in the immediate and intermediate future an 85% reduction in total ammonia is clearly indicated. Since it may be assumed that the background levels cannot be significantly improved, the three major sources of ammonia must be collectively reduced by 91% to a total of 331 pounds per day. On a proportional basis, the Brainerd sewage treatment plant should discharge not more than 34 pounds per day; FCA ammonia discharge should be reduced to not more than 119 pounds per day; and Southeast Polymers-Burkhart-Schier combined waste should not exceed 178 pounds per day. Based on a 650,000 gallon per day flow from FCA, the ammonia concentration in the effluent should not exceed 22 mg/l. Equivalent reductions should also be made in the organic nitrogen and nitrite-nitrate concentrations of these discharges.

If ammonia input is reduced as described, no toxic effects should be observed as the result of ammonia alone in South Chickamauga Creek. However, it should be emphasized that aquatic degradation may continue in the creek unless strict control is placed over all industrial discharge to this stream. Due to synergistic effects observed with ammonia in combination with other compounds; increased toxicity of ammonia when

in an environment of high pH and low DO; or the singular toxicity of other pollutants, reduction of just one compound may not result in a significant improvement in the aquatic community in South Chickamauga Creek.

Although recommended discharge criteria discussed here will provide a satisfactory environment for aquatic propagation in South Chickamauga Creek, ammonia concentrations in Friar Branch would remain toxic to fish life. It is considered impractical to restrict waste discharge in Friar Branch to such a degree that ammonia concentrations do not exceed 1.5 mg/l since natural flow in the stream is so small as to offer only limited dilution potential and the lack of suitable topography suggests a relatively poor environment for aquatic propagation. If Friar Branch is to be classified for aquatic propagation, it appears necessary to divert waste into other receiving waters or to entirely remove these effluents from the basin area possibly through connection to the municipal sewer system, or through the installation of a closed system.

IX. CHLORINE DEMAND EVALUATION

High chlorine demands at the Chattanooga Water Company had been recorded most frequently during periods of low river flow and elevation. A few days before this survey was performed, TVA had completed its milfoil weed control program which included restricting flows and reducing river elevation, and was discharging from October 14-21, 1968 at a relatively high rate of about 30,000 cfs. Chlorine demands averaged in the normal range of 30-40 pounds per million gallons during the study and consequently, the most critical conditions for chlorine demand were not observed. Flow patterns in the lake from South Chickamauga Creek were obscured by the increased volume of water flowing through the channel.

In an effort to identify conditions prevailing during high chlorine demand periods, historical data were examined, including the predominant factors thought to influence the water quality at the treatment plant intake. Data were obtained from the operating log sheets of the Chattanooga Water Company, from U. S. Geological Survey river gauging stations and from FCA for the period July 1-October 20, 1968. The following is a discussion of the evaluation performed and the conclusions derived from this analysis.

A. Chlorine Demand and Ammonia Concentration

Chemical analyses are performed on the raw water at the Chattanooga water plant on a routine basis by plant chemists as a quality control technique. Among these tests, a direct nesslerization analysis for ammonia is performed once each day during the mid-morning period. Although the technique utilized in this particular test has

been shown to provide considerable variation in absolute results, the relative accuracy of the analyses at the water plant were accepted as being correct. (Recent conversations with the plant's chief chemist would indicate that procedures utilized in the analyses recorded over the period examined may have been in the order of 25% lower than the actual concentrations.) The water plant also maintains logs indicating chlorine requirements for each two-hour period. A test for free chlorine residual is measured at the end of this period on the finished water pumped into the city mains. The period of retention in the plant was reported to be approximately six hours under normal operating conditions. The actual chlorine consumed in the treatment process was computed by summing the total chlorine added during treatment and then subtracting the free chlorine residual existing at the end of the process, six hours later. This figure for chlorine consumed in the chemical treatment process, was computed for each week day for the period August -October 1968 based upon the 7:00 am to 9:00 am data. FIGURE 12 shows the relationship between chlorine consumed during the treatment process and ammonia analysis performed at the water plant during the corresponding period.

As might be expected, chlorine demand varies directly with ammonia concentration in the raw water. However, with closer observation, a few other important conclusions may be drawn.

The slope of the linear regression of best fit through these points passes through an intercept value of 6.5 pounds of chlorine per million gallons of water treated. This may be interpreted as the chlorine demand of background contaminants since, theorectically, if the water contained no other such contaminants the chlorine consumed would be zero. If this background demand were subtracted from each individual

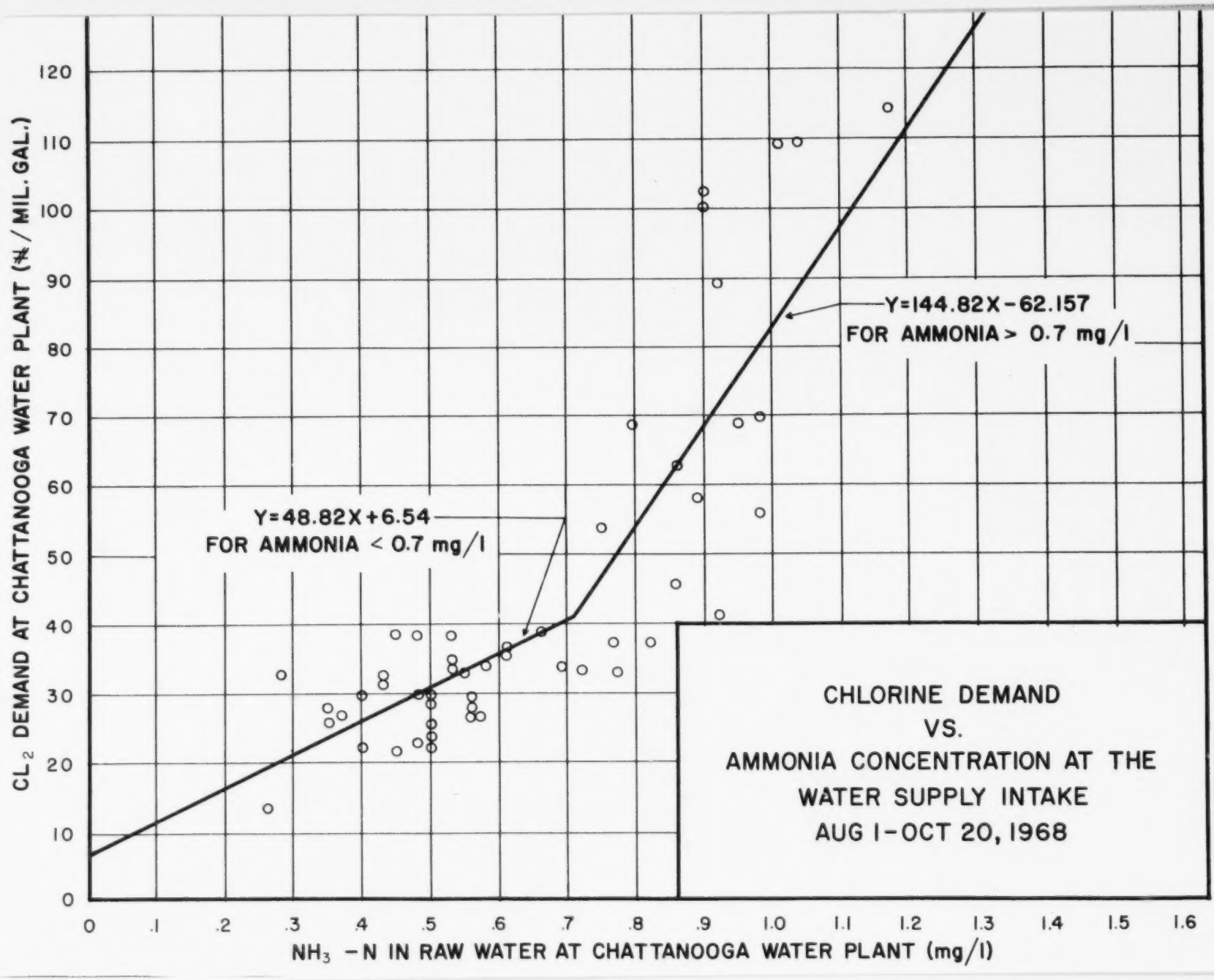
CL_2 DEMAND AT CHATTANOOGA WATER PLANT (#/MIL. GAL.)
120
110
100
90
80
70
60
50
40
30
20
10
0
Y=144.82X-62.157
FOR AMMONIA > 0.7 mg/l
Y=48.82X+6.54
FOR AMMONIA < 0.7 mg/l
CHLORINE DEMAND
VS.
AMMONIA CONCENTRATION AT THE
WATER SUPPLY INTAKE
AUG 1-OCT 20, 1968
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
NH_3 -N IN RAW WATER AT CHATTANOOGA WATER PLANT (mg/l)

Figure 12

measurement the resulting straight line, for ammonia concentrations in the range 0 to 0.70 mg/l, would pass through the origin and have a slope indicating approximately 49 pounds of chlorine would be required per mg/l of ammonia. This rate is less than the theoretical chlorine demand as calculated from empirical chemical considerations. It is postulated that, at concentrations between 0 and 0.7 mg/l of ammonia in Nickajack Lake, the increase in chlorine demand at the water plant is caused entirely by increases in ammonia concentrations.

At a point, corresponding to about 0.7 mg/l of ammonia, a distinct break in the distribution is observed. At this point, chlorine demand increases at a much higher rate with respect to increases in ammonia concentration. The slope of this line is nearly three times that of the line passing through points of lower concentration, indicating a rate of three times the consumption of chlorine over the lower range. Although the increase in chlorine demand with ammonia concentration is still a linear function above 0.7 mg/l of ammonia, the rate of increase indicates that other materials with high chlorine demands are accounting for nearly two-thirds of the increased demand. Therefore, increases in ammonia concentration above 0.7 mg/l in Nickajack Lake are not the principal causative agent of the increased chlorine demands. Since this condition appears to occur when ammonia concentrations exceed 0.7 mg/l, the abrupt change in chlorine consumption rates suggest changes of composition or origin of the organic materials entering the water plant intake.

B. Chlorine Demand and Nickajack Lake Discharge

Data was compiled from the U. S. Geological Survey gauging station in Nickajack Lake (Station 3-5680.00), including discharge and river stage. These data show that during periods of low flow an increased chlorine demand is observed. FIGURE 13 illustrates that although average daily chlorine demand does appear to vary inversely with river flow, peaks and valleys of one condition do not correspond exactly day to day with the other. The possibility of a delayed and/or cumulative effect was postulated.

Various sets of river flow data were compared to average daily chlorine demands, including the flows for the same day, the day before, two days before, three days before (etc.); an average of the three days flow preceding, and for five and seven days preceding. The set of data indicating the best overall statistical correlation was between average daily chlorine demand and the average flow for the previous seven days. This statistical study indicates that a cumulative effect does exist during periods of high chlorine demand. A duration of approximately seven days of low flow (less than 14,000 cfs) and lowered stage correlates with excessively high chlorine demands. The lower the seven day flow, the higher the demands, as shown in the accompanying FIGURE 14. Apparently the significant break occurs when river flows drop below an average of about 14,000 cfs. It is hypothesized that under high flow conditions (above 14,000 cfs), turbulent mixing is accomplished, vertically and laterally. A change in flow regime in this range causes a variation in chlorine demand; however, the variation is relatively small since mixing is thorough. At flow rates

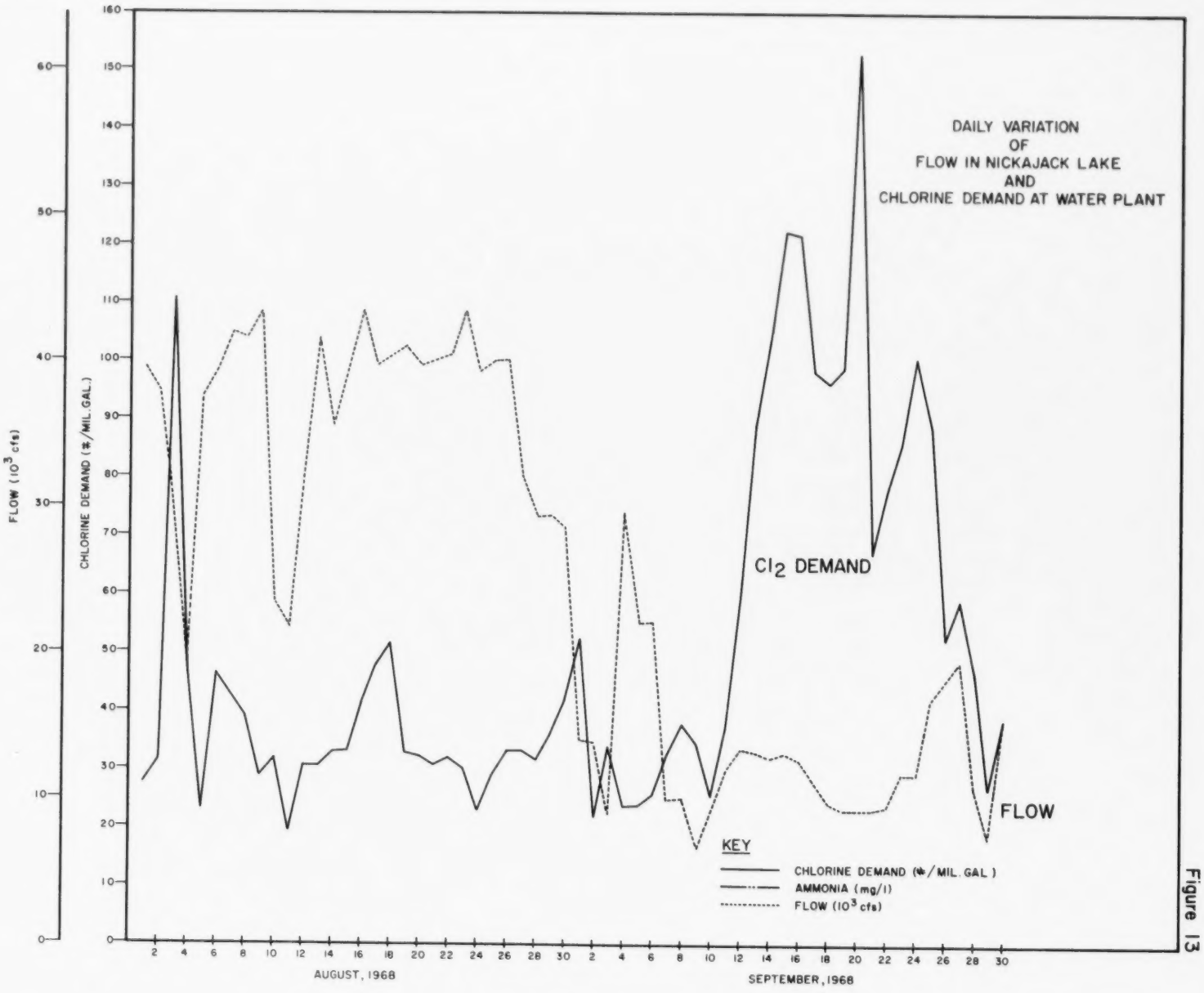
DAILY VARIATION
OF
FLOW IN NICKAJACK LAKE
AND
CHLORINE DEMAND AT WATER PLANT
FLOW (10^3 cfs)
CHLORINE DEMAND (#/MIL. GAL.)
Cl_2 DEMAND
FLOW
KEY
CHLORINE DEMAND (#/MIL. GAL.)
AMMONIA (mg/l)
FLOW (10^3 cfs)
AUGUST, 1968
SEPTEMBER, 1968

Figure 13

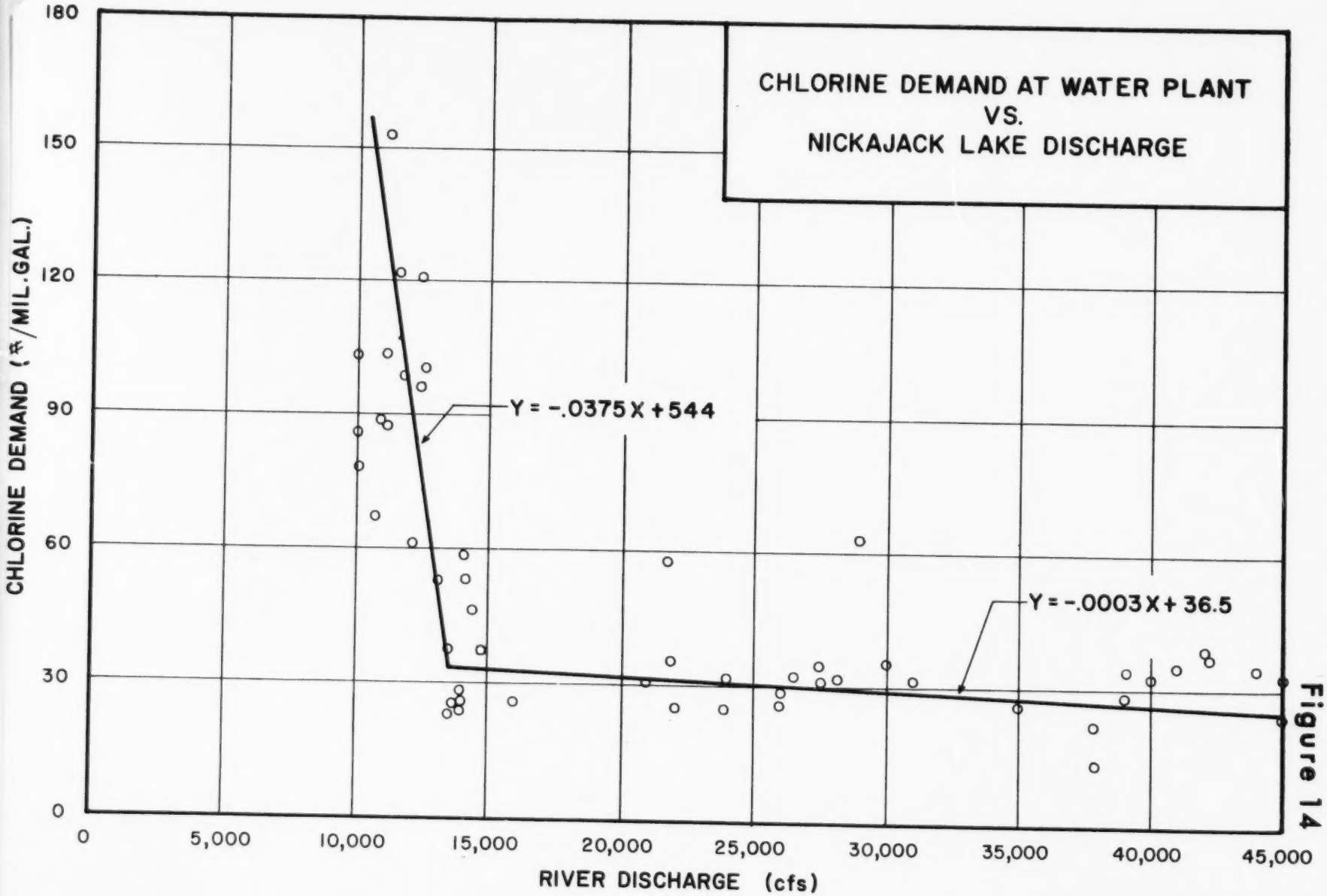
CHLORINE DEMAND AT WATER PLANT
VS.
NICKAJACK LAKE DISCHARGE
Y = -.0375X + 544
Y = -.0003X + 36.5
CHLORINE DEMAND (#/MIL.GAL.)
RIVER DISCHARGE (cfs)
0
30
60
90
120
150
180
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000

Figure 14

in the range of 12,000-15,000 cfs complete mixing in the reservoir begins to give way to a stratified condition, with an accompanying reduction in mixing ability. The significance of a seven day delay in achieving high chlorine demands at the plant can be postulated as the period necessary to eliminate transient eddies and local turbulence which continue to stir the emerging stream lines. Once the stream lines are fully formed, effluent from tributaries on the east side of the lake may enter and flow slowly downstream, undergoing minimum dilution. Since waste is only moderately diluted it may enter the water plant intake in significant concentrations.

It is important to note that the sharp break in continuity in both the curves for chlorine demand when compared to ammonia concentration at the plant, and with flow in Nickajack Lake occurs at approximately the same level thirty-five to forty pounds of chlorine per million gallons processed. Apparently, the action of the river flow has an influence on the composition of the waste entering the water plant.

If it is first assumed that the organic material entering the water plant and causing excessive demands originates in South Chickamauga Creek, then the chlorine demand would be expected to increase linearly with a constant slope as the ammonia concentration increased, since there is no evidence to indicate that the characteristics of the waste leaving the mouth of this creek vary considerably unless slug discharges are made from the waste sources. Lateral stratification of waste from South Chickamauga Creek in Nickajack Reservoir would partially account for higher ammonia concentrations at the water intake but the pronounced change in slope indicates that this represents only a proportional increase of the chlorine demand, since it cannot exceed the

theoretical demand of ammonia. Therefore, this change in slope must show a change in waste composition. Under the conditions described, the excessively high chlorine demands experienced at the water plant are at least in part, the result of waste entering the lake at some point other than South Chickamauga Creek.

Although it is possible that other sources are contributing waste under low flow conditions, most of the evidence indicates Citico Creek as the source of contaminants. In light of the foregoing discussion, the following is a list of evidence which points to this source.

(1) A high degree of pollution was shown at the mouth of Citico Creek which could influence chlorine consumption in the water plant's disinfection process. Studies showed high concentration of phenols, high COD, high alkalinity and high organic carbon as well as ammonia concentrations higher than at the mouth of South Chickamauga Creek.

(2) Under completely mixed flow conditions in the river, discharge from Citico Creek is carried directly downstream. When stratified conditions prevail under reduced river flow and stage, some water could flow out of Citico Creek and enter the water plant intake, located just 50 feet upstream and about 400 feet from the shore, This condition has been previously reported and confirmed by oil slicks in the plant's filter beds.

(3) The fact that contaminants having a high chlorine demand enter the plant only during low flow periods fits the hypothesis. This conclusion would explain the reason why chlorine demand increase does not coincide proportionally with ammonia increase.

(4) Any other waste source known to be present in the area would require crossing from the west shore of the lake as well as flowing a distance of at least three miles. A considerable dilution would almost certainly occur.

The location of the Chattanooga Water Company intake is shown in FIGURE 15. As can be observed, the main intake lines are so located to almost certainly be influenced by wastes being dispersed from Citico Creek into Nickajack Lake. The configuration of the shoreline would bring wastes from Citico Creek directly toward the intake. The location of the water supply intake represents a health hazard even if all continuous waste discharges to South Chickamauga Creek and Citico Creek were eliminated which does not appear feasible in the immediate future. Drainage from the dispersed operations in the many industrial installations in the area would continue to affect the intake location. Therefore, it is recommended that the flow from Citico Creek be diverted downstream by construction of a dike into thelake from the eastern shore of the creek. The water supply intake should also be extended upstream and further out into the lake to mitigate the influence of wastes discharged from South Chickamauga Creek. Until these recommendations can be accomplished, the TVA should maintain a minimum daily flow of 14,000 cfs in Nickajack Lake.

C. Chlorine Demand and South Chickamauga Creek Flow

During the period of investigation, little variation in the flow of South Chickamauga Creek was observed. Maximum creek discharge was recorded as 248 cfs and minimum flow was 128 cfs during the period August 1 - October 20, 1968. The small range of variation was obscured by the larger variation in the Tennessee river flow and consequently a true

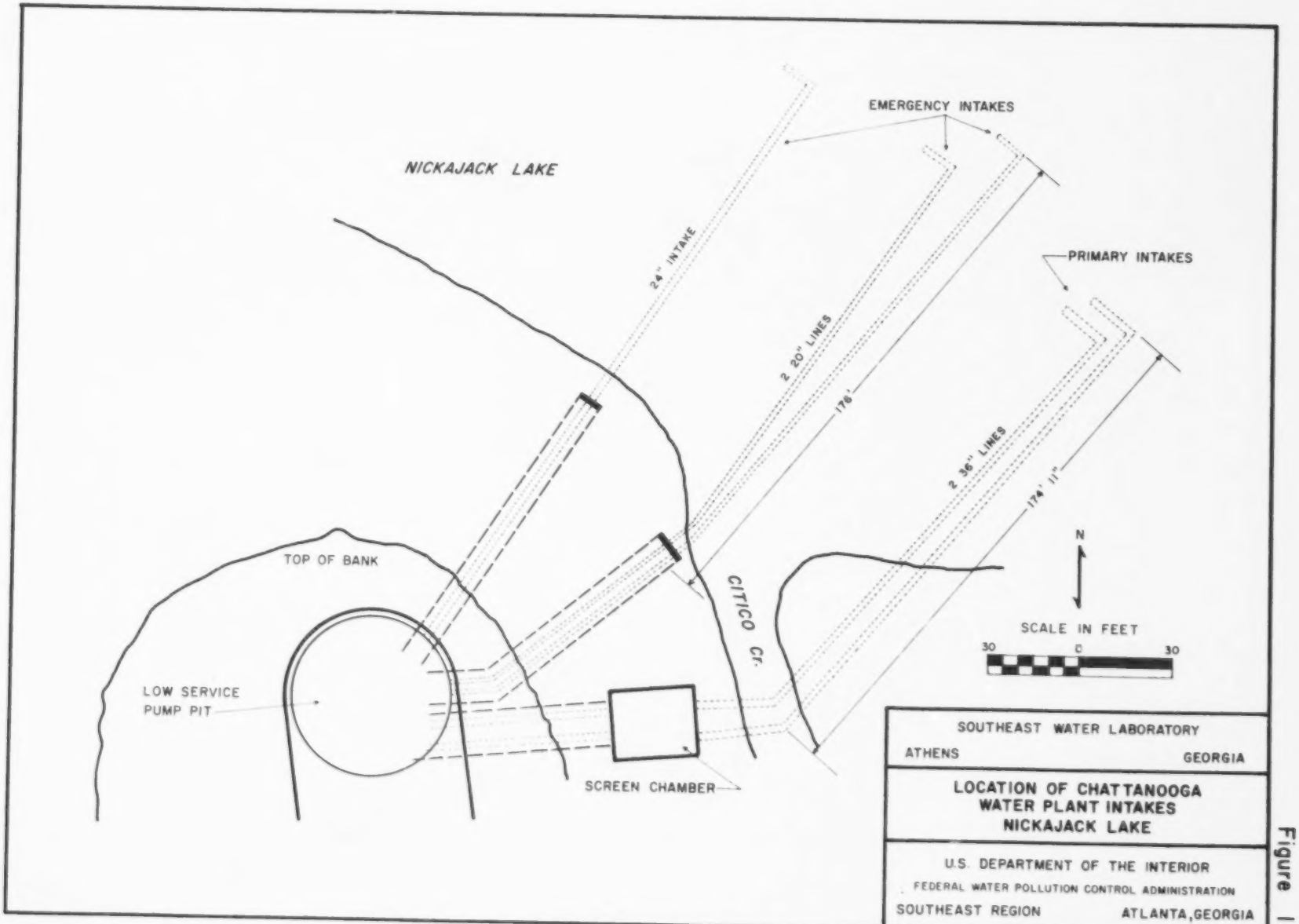
NICKAJACK LAKE
EMERGENCY INTAKES
PRIMARY INTAKES
24" INTAKE
2 20" LINES
176'
2 36" LINES
174' 11"
CITICO CR.
TOP OF BANK
LOW SERVICE
PUMP PIT
SCREEN CHAMBER
N
SCALE IN FEET
30
0
30
SOUTHEAST WATER LABORATORY
ATHENS
GEORGIA
LOCATION OF CHATTANOOGA
WATER PLANT INTAKES
NICKAJACK LAKE
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
SOUTHEAST REGION
ATLANTA, GEORGIA

Figure 15

statistical evaluation of this parameter could not be assessed.

D. Chlorine Demand and FCA Ammonia Effluent

Chemical analyses were performed during the period July - October, 1968 by TVA and an independent testing laboratory in Chattanooga on the FCA plant effluent. Both direct and distilled nesslerization tests were made to determine the ammonia discharge from the Farmers Plant and its effect on points downstream. These analyses show a progressive reduction in ammonia content over the past several months. However, too few analyses were performed during the period to reveal a true statistical correlation with chlorine demand data at the Chattanooga water plant. Of the twenty sets of data available, only one was performed during the period of high chlorine demand. For discussion purposes, however, FIGURE 16 reveals a distinct trend of increasing chlorine demand with increasing ammonia discharge rates from the plant. Volume of flow was considered to be constant. Waste discharged at the FCA plant does play a major role in the chlorine demand requirements at the water plant. A doubling of ammonia waste discharge from the FCA plant will result in a 17% increase in chlorine requirements at the water plant for FCA effluent ammonia concentrations between 500 - 1,000 mg/l and under flow conditions in Nickajack Lake greater than 14,000 cfs. However, under low flow conditions (14,000 cfs) the effect is overshadowed by waste entering from Citico Creek. By projection of the lower curve defining the demand exerted by ammonia (FIGURE 12), it is estimated that a maximum of 62 pounds pf chlorine per million gallons of water could be attributed to ammonia waste from South Chickamauga Creek under the conditions prevailing during the period in September when demands were recorded at 130 pounds per million gallons.

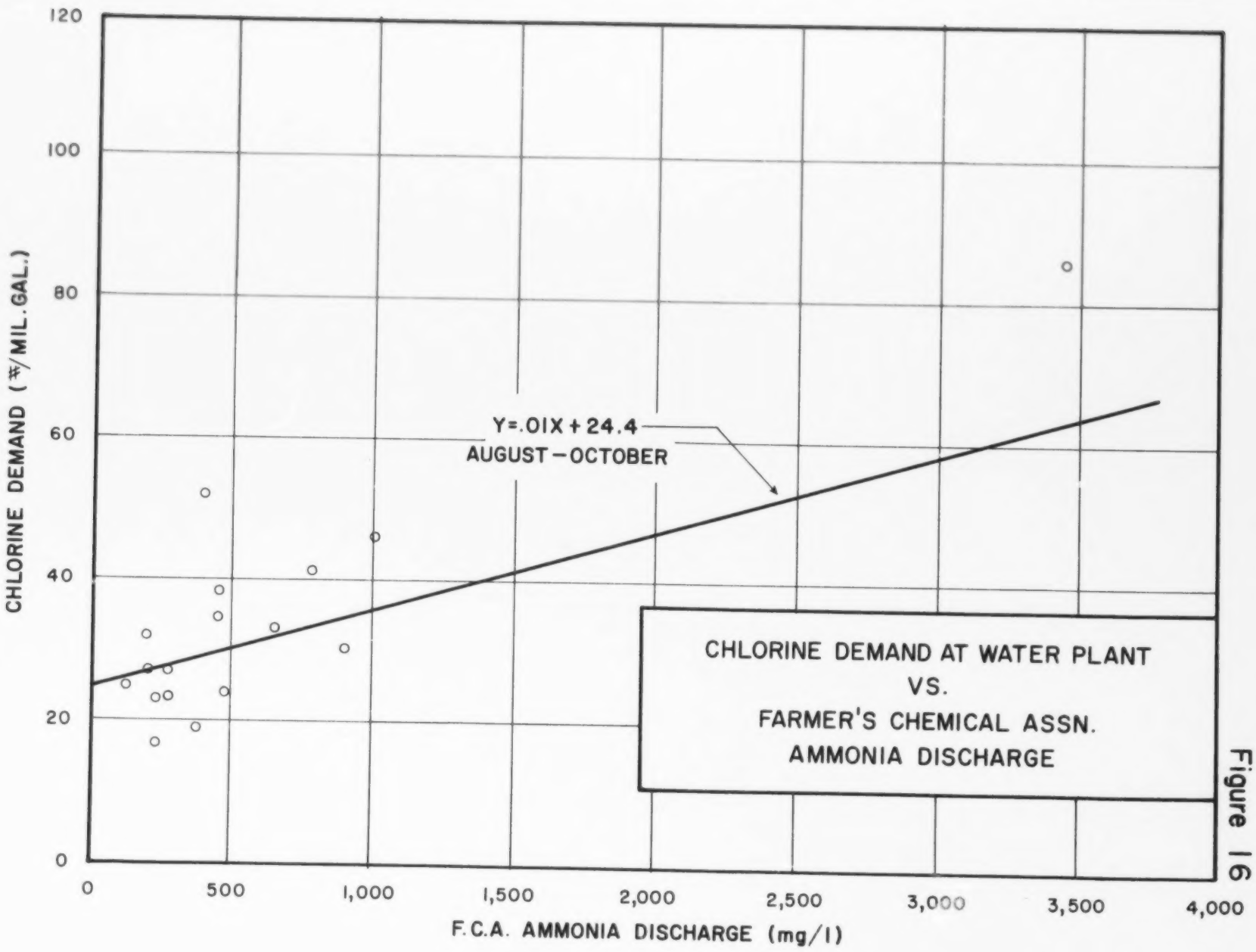
120
100
80
60
40
20
0
CHLORINE DEMAND (#/MIL. GAL.)
Y=.01X + 24.4
AUGUST – OCTOBER
CHLORINE DEMAND AT WATER PLANT
VS.
FARMER'S CHEMICAL ASSN.
AMMONIA DISCHARGE
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
F.C.A. AMMONIA DISCHARGE (mg/l)

Figure 16

Under the conditions observed during the survey, it is estimated that FCA accounted for one-third of the chlorine demand at the water plant, attributable to discharges from South Chickamauga Creek.

X. ACKNOWLEDGEMENTS

The following people and organizations contributed substantially to the preparation and substance of this report.

The State of Tennessee Division of Stream Pollution Control and, in particular, Mr. E. H. Hockensmith, provided invaluable assistance in the formulation and review of the study procedures and in supplying necessary waste inventory information.

Farmers Chemical Association represented by Mr. Edward C. Bingham, Jr., Technical Assistant to the Manager, and his staff provided unlimited access to the plant as well as complete mobility within the FCA area in selecting sampling locations. Data concerning volume and quality of the waste discharge were also supplied. Lt. Col. James Slater, Director of the Volunteer Army Ammunition Plant also extended the cooperationoof the United States Army and provided background information on waste abatement plans and schedules.

Mr. William Neuman, Chief Chemist of the Chattanooga Water Company transmitted historical data on chlorine demand and ammonia concentration at the water plant and precisely specified the location of the water plant intake.

The Tennessee Valley Authority by its cooperation on water releases, transmittal of water release data and by its general interest in all aspects of this study, has again demonstrated its long standing commitment to high quality water in the Tennessee Valley.

Mr. Dennis Cafaro, Sanitary Engineer at the Southeast Water Laboratory of FWPCA supervised certain portions of the field study and performed many of the statistical analyses. Thomas P. Gallagher, Chief of Engineering Services at Southeast Water Laboratory provided insights and suggestions for data analysis and evaluation and exercised overall direction.

Finally, but certainly of most importance, Mrs. Elayne P. Cook by her typing, editing and corrections contributed materially to the literacy of this report. Her perseverance and forebearance are gratefully appreciated.

APPENDICES

APPENDIX A

HYDROLOGICAL PROCEDURES

The waste that flows to South Chickamauga Creek from the Farmers Chemical industrial complex follows the natural configuration of the terrain. The waste flows were measured at four sites within the industrial reservation by weirs. The last measuring site is a pond that is operated on a flow through basis. This pond has a storage retention time of five days and is used to contain and neutralize any major spills. The waste leaves the reservation and flows into another smaller pond that has an undetermined retention time. From this pond, the waste flows 1.2 miles in a tree clogged ditch through a small swampy area and into Friar Branch. There is one perennial branch that joins the ditch above Friar Branch.

Friar Branch is a perennial stream with low banks and a wide channel in most of the basin. However, as the stream approaches South Chickamauga Creek the channel becomes narrow and the banks are high. The waste from FCA joins Friar Branch approximately 1.5 miles above the mouth. The flow in Friar Branch moves through large pools and short riffles throughout the basin.

The measured discharge on October 16, 1968 at Station FB-6 was 5.4 cfs. There are no statistical data available concerning the flows in Friar Branch.

Friar Branch joins South Chickamauga Creek 8.2 miles above its mouth. South Chickamauga Creek has a wide channel with banks as high as twenty feet. At low flow, the water moves through long pools and

short riffles above the backwater from Nickajack Lake. In the backwater area the depth is dependent on the lake elevation.

Flow records are collected at a point 12.4 miles above the mouth by the U. S. Geological Survey. The arithmetic average flow on South Chickamauga Creek at this station is 682 cfs based on 38 years of continuous records. This flow is equalled or exceeded 24% of the time. The seven consecutive day low flow with a recurrence interval of ten years is 82 cfs, based on 37 years of record. This flow is equalled or exceeded more than 99% of the time. The three consecutive day low flow with a recurrence interval of 20 years is 73 cfs. The lowest flow recorded at that station was 61 cfs on October 8, 1941.

South Chickamauga Creek empties into the Tennessee River approximately one mile below Chickamauga Dam. The Tennessee River impoundment in the Chattanooga vicinity is Nickajack Lake which is downstream from Chickamauga Dam. Nickajack Lake is part of the TVA system and the flow of water through the entire system is regulated hourly by a computer. Generation patterns and general operations of the hydro-electric plants is dictated by the amount of rainfall in the upper part of the Tennessee River basin.

The average daily flow of the Tennessee River at Chattanooga is 36,960 cfs, based on 92 years of record. Statistical evaluations of low flow conditions are not significant because of the control of the flow by the locks and dams. There could be periods during daily operations when there is only tributary flow in the river at Chattanooga. The minimum daily flow at Chattanooga since filling Hales Bar pool which preceded Nickajack Lake was 1200 cfs on November 1, 1953. Flow

regulation at Chickamauga Dam was started in 1941. Examination of records since that year show the seven day low flow with a ten year recurrence interval as being 12,200 cfs.

A dye tracer study was made to determine the travel time of waste from the FCA pond to the Tennessee River. The dye tracer study was started by injecting approximately ten gallons of Rhodamine WT dye at the outfall of the lower pond, (Station PB-2). The average velocity was determined by using the time of travel of the peak concentrations of dye.

TABLE A-7 shows the average velocities between sampling stations. The time of travel was not determined within the industrial complex.

The flow in Friar Branch at Station FB-6 was measured at 5.4 cfs as the peak concentration of the dye was passing. The flow in South Chickamauga Creek at the U.S.G.S. gauging station was 137 cfs during the time of the study. The inflow from Friar Branch was 5.4 cfs and other inflow for outfalls was estimated at 3.6 cfs, giving a total flow in South Chickamauga Creek in the study area of 146 cfs.

During the study, Nickajack Lake was two feet lower than normal because of the milfoil weed control program being conducted by TVA. The flow in the Tennessee River during the study period varied from 27,000 to 32,300 cfs.

The dye study covered 11.86 miles in Friar Branch and South Chickamauga Creek in 68.3 hours for an average velocity of 0.17 mph.

Dilution characteristics by volume of flow from Friar Branch into South Chickamauga Creek were 5.4 cfs into 137 cfs or 1 to 25 during the survey. However, the peak concentrations of dye indicated a dilution

ratio of 16.6 to 1 from Friar Branch into South Chickamauga Creek. Dye concentrations in the Tennessee River were below significant limits.

TABLE A-I

Stations	Miles	Time of Travel (Hrs.)	Avg. Velocity (mph)
PB-2 to FB-5	2.16	20.5	0.10
FB-5 to FB-6	1.19	9.6	0.12
FB-6 to CC-9	0.96	4.0	0.24
CC-9 to CC-10	2.98	8.7	0.35
CC-10 to CC-11	1.86	4.0	0.46
CC-11 to CC-12	2.71	21.5	0.13
CC-9 to CC-12	7.55	34.2	0.25
PB-2 to CC-12	11.86	68.3	0.17

APPENDIX B

BIOLOGICAL PROCEDURES

A biological survey of Friar Branch and South Chickamauga Creek was conducted from October 15-19, 1968. The purpose of this survey was to determine the toxicity of ammonia on certain aquatic life, and (if toxic) the length of water way adversely affected.

Benthos Study

The aquatic community structure is a reflection of the water quality. Lack of time often necessitates a limited study; hence, many aquatic biologists rely on observed changed in certain populations within the aquatic community. The group chosen for study in this survey was the bottom-dwelling or benthic invertebrate community. The following statements are an oversimplification of biological phenomena but are used to stress the importance of changes in benthic communities as a reflection of pollution.

The invertebrate community response differs according to the degree and type of pollution. Organic pollution causes a reduction or sometimes eliminates dissolved oxygen in the stream. Consequently, the invertebrate community structure changes sharply. Sensitive forms are replaced by large numbers of the few organisms that can tolerate the lowered dissolved oxygen content.

Toxic pollution affects the community differently. Both sensitive and tolerant organisms (with respect to organic pollution) are adversely affected by the toxicants. The result is that the total number of organisms is reduced.

A comparison of the invertebrates collected at Station CC-8 and CC-9 indicated that both organic enrichment and toxic materials were present in South Chickamauga Creek. As mentioned above, species diversity is reduced by organic pollution. One method of expressing this reduction is through the use of the McIntosh Diversity Index (McIntosh, 1967). Briefly, this Index is one of the many recent attempts to express community diversity as a single number. The Index is expressed as:

$$I = \sqrt{\sum_{i=1}^{S} n_i^2}$$

S = number of species

n = number of individuals in each species

An index value of 1.00 represents complete diversity while a value of 0.0 represents complete homogeneity.

TABLE A-II shows that species diversity was appreciably lower at Station CC-8 than at Station CC-9 (McIntosh Diversity Index of 0.56 and 0.73, respectively). This difference indicated that the area of South Chickamauga Creek upstream from the Friar Branch junction (Station CC-8) was more organically enriched than an area immediately downstream from the junction (Station CC-9).

With respect to toxicity, Station CC-8 collections contained 134 organisms per square foot while Station CC-9 contained 90 organisms per square foot. The trend toward a decreased population at Station CC-9 was not extremely pronounced but was sufficient to indicate that toxic wastes had entered South Chickamauga Creek from Friar Branch.

Bioassay Study

The in-situ bioassay substantiated the fact that toxic materials had entered South Chickamauga Creek from Friar Branch and that these toxicants

TABLE A-II

BENTHOS FROM SOUTH CHICKAMAUGA CREEK, TENNESSEE

(number of organisms per sq. ft.)

ORGANISM	STATION	
	CC-8	CC-9
Phylum Platyhelminthes		
Class Turbellaria		
Order Tricladida		
Family Planariidae (planaria)		
Dugesia sp.	1	
Phylum Annelida		
Class Oligochaeta		
Order Plesiopora		
Family Tubificidae (aquatic earthworm)		
Limnodrilus sp.		5
Class Hirudinae (leech)	1	
Phylum Arthopoda		
Class Crustacea		
Order Isopoda		
Family Asellidae (aquatic sow bug)		
Lirceus sp.		1
Class Insecta		
Order Ephemeroptera		
Family Heptageniidae (mayfly)		
Stenonema proximum Traver	5	
Stenonema sp.	7	2
Family Baetidae (mayfly)		
Baetis sp. 1	16	
Baetis sp. 2	1	
Baetis sp. 3	1	
Pseudocloeon sp.		1
Order Trichoptera		
Family Hydropsychidae (caddisfly)		
Cheumatopsyche sp.	58	1
Hydropsyche sp.	22	3
Order Diptera		
Family Simuliidae (blackfly)		
Simulium sp.		4
Family Chironominidae (midge)		
Conchapelopia sp.		2
Cricotopus bicinctus (Meiger)	7	23
Pentaneurini		1
Orthocladiinae	2	
Chironomus decorus (Johannsen)		4

TABLE A-II CONT'D.

Benthos From South Chickamauga Creek, Tennessee

ORGANISM	STATION	
	CC-8	CC-9
Chironomini		
Harnishchia sp.		1
Polypedilum illinoense (Malloch)	6	1
Polypedilum tritum (Walker)		16
Polypedilum sp.		1
Rheotanytarsus exiguus (Johannsen)		1
Tanytarsus sp.		6
Chironomidae (pupa)		1
		8
Order Coleoptera		
Family Elmidae (elmid beetle)		
Stenelmis sp. (adult)	1	3
Stenelmis sp. (larvae)		2
Phylum Mollusca		
Class Gastropoda		
Order Pulmonata		
Family Ancylidae (limpet)		
Ferrissia sp.	2	
Family Physidue (pounh snail)		3
Physa sp.		
Class Pelecypoda		
Order Eulamellibranchiata		
Family Cyrenidae (asiatic clam)		
Corbicula sp.	4	
Number of species	15	22
Total number of Organisms	134	90
McIntosh Diversity Index	.56	.73

affected the Station CC-9 area. Fathead minnows survived less than 24 hours at the mouth of Friar Branch. The waste water from Farmers Chemical Association enters Friar Branch between Stations FB-3 and FB-5, yet test fish survived longer at Station FB-5 than downstream at Station FB-6. These data indicate that additional toxicants (possibly a synergistic action) entered Friar Branch between Stations FB-5 and FB-6. The Southeast Polymers - Burkhart Schier outfalls are located between FB-5 and FB-6. The toxic water in Friar Branch was diluted as it flowed into South Chickamauga Creek. Bioassay results at Stations CC-9 and CC-10 showed 90% survival of test fish during a 96-hour exposure. Station CC-11 provided a suitable habitat for test fish during the survey and no dead fish were recorded.

The industrial effluents near Station CC-12 dictated the use of two test fish cages in this area. One cage was submerged at a two foot depth near the left bank and one near the right bank (approximately 15 feet from each shoreline). The Stations were designated as CC-12N (right bank facing downstream) and CC-12S (left bank facing downstream).

An industrial effluent flowed into Chickamauga Creek from the left shoreline (facing downstream) approximately 300 yards upstream from Station CC-12S. The effluent caused a milky discoloration in the creek that stratified along the left shoreline past Station CC-12S and continued downstream from an undetermined distance. Fathead minnows at Station CC-12S were exposed to the discolored water and within 48 hours 30% of the fish were dead. Twenty-four hours later, 50% of the fish were dead. The remaining 50% of the fish survived the 96-hour bioassay. Fathead minnows at Station CC-12N were not observed to be exposed to the discolored industrial waste water and all the fish survived the 96-hour

test. Events described above may have been circumstantial but it is reasonable to conclude that the observed industrial waste water in this vicinity was responsible for killing the test fish at Station CC-12S.

APPENDIX C

CHEMICAL PROCEDURES

I. METHODS: All analytical methods used to analyze the samples from this survey were the standard procedures employed at the SEWL. No statistical evaluation of the precision of the methods was carried out on these samples.

A. Nitrogen Series: The three analyses included in the nitrogen series are completely automated by use of the Technicon Auto-Analyzer. A brief description of each method follows.

1. Ammonia (NH_3 as N). The methdd is based on measuring the intensity of the indophenol blue color formed by the reaction of ammonia with alkaline phenol hypochlorite. Sodium nitroprusside is employed to intensify the color whose absorbance is determined by use of a colorimeter equipped with a 630 mu filter.

2. Nitrate-Nitrite (NO_3-NO_2 as N). In this method nitrates are reduced to nitrites by the action of a cadmium-copper catalyst. The nitrites are then reacted with sulfanilamide to form the diazo compound, which is then crystalized in acid solution with N-1 naphthylethylenediamine hydrochloride to form the azo dye. The reddish purple color is measured by means of a colorimeter at 520 mu. This method accounts for the total nitrate-nitrite concentration.

3. Total Kjeldahl Nitrogen (TKN). The sample is digested with a sulfuric acid solution containing potassium sulfate and mercuric sulfate as a catalyst to convert organic nitrogen to ammonium sulfate. This digestion takes place in 3 stages at 390°C, 350°C and 310°C. The solution is then neutralized with sodium

hydroxide and treated with alkaline phenol and sodium hypochlorite. This forms an indophenol blue color which is measured by a colorimeter at 630 mu.

B. Chemical Oxygen Demand (COD). Fifty ml aliquots of the samples were digested under reflux with 0.025 N potassium dichromate and concentrated sulfuric acid. The excess dichromate was titrated with standard ferrous ammonium sulfate. The amount of oxidizable organic matter is proportional to the amount of dichromate consumed. Reference for this analysis is the 12th Edition of Standard Methods.

C. Phenols (12th Edition, Standard Methods). The distillation procedure followed by color development with 4-amino-antipyrine and potassium ferricyanide, and concentration by chloroform extraction was used for phenol analyses. The sensitivity of this procedure is 1 ppb and covers the phenol concentration range of 0.0 - 1,000 ppb.

D. Total Alkalinity (12th Edition, Standard Methods). The procedure involved the titration of an aliquot of sample with 0.02 N sulfuric acid to an end-point detected by the use of a mixed bromcresol green-methyl red indicator solution. The results were reported in mg/l alkalinity as $CaCO_3$.

E. Total Chromium. The chromium analyses on the picked samples were run by atomic absorption analysis. The procedures involved no concentration of sample. The analysis itself was run using a Perkin Elmer Model 303 Atomic Absorption Spectrophotometer with scale expansion and recorder readout.

F. Total and Inorganic Carbon. These analyses were carried out with the Beckman Model 915 Total Carbon Analyzer. A sample size of 20 ul was used. All samples were run in triplicate.

II. "BREAK-POINT CHLORINATION" Chlorination of a water to the extent that all the ammonia is converted to trichloramine or oxidized to free nitrogen or other gases is referred to as break-point chlorination. When chlorine is added to water containing reducing agents and ammonia, it first reacts with the reducing agents developing no measurable residual. Next the chlorine combines with the ammonia in a 1:1 ratio to form both monochloramines and dichloramines. The amounts of each are determined mainly by pH. When all the ammonia has been reacted with a free available chlorine residual develops. As this residualiincreases the chloramines are oxidized forming nitrous oxide, nitrogen and nitrogen trichloride. This causes a reduction in the chlorine residual. The completion of this oxidation is known as the "break-point." The reactions are essentially complete when 2 moles of chlorine have been added for each mole of ammonia nitrogen. Further chlorination produces free chlorine residuals.

The following gives the calculations for determining the amount of chlorine required to treat 1 million gallons of a water containing 1 ppm ammonia (NH_3).

one mole NH_3 = 17 g. or 17 lbs.

one mole Cl_2 = 71 g. or 71 lbs.

$NH_3 + 2Cl_2 \longrightarrow$ break-point

17 lb. NH_3 + 142 lbs. $Cl_2 \longrightarrow$ break-point

1 lb. NH_3 + 8.35 lbs. $Cl_2 \longrightarrow$ break-point

1 ppm NH_3 = 8.34 lbs/million gals.

$$\frac{8.36 \text{ lbs. } NH_3}{\text{million gal.}} \times \frac{8.35 \text{ lbs. } Cl_2}{16.0 \ NH_3} = 69.7 \text{ lbs. } Cl_2/\text{million gals.}$$

Therefore it would require 69.7 lbs. Cl_2/million gals. to treat a 1 ppm ammonia as NH_3.

APPENDIX D

SUMMARY OF OBSERVED DATA

October 15, 1968

Station	Flow Rate (cfs)	Temp. °C	Ph	DO (mg/l)	NH_3-N (mg/l)	(NO_2-NO_3)-N (mg/l)	Kjeldahl N (mg/l)	COD (mg/l)	TOC (mg/l)	TIOC (mg/l)	Phenols ppb	Alk. ppm
FCA-1	0.64	36.0			100	60	110					
-2	0.20	37.0			65.0	420	76.0					
-3	0.84	37.0			90.0	165	109					
-4	0.05	34.5			1090	1000	1212					
-5a		46.0			1550	1010	1763					
-4b		56.0			900	885	922					
-5		32.0			165	250	172					
-6	0.81	30.0			160	230	167					
-7		23.5			12.5	16.7	16.3					
-7a		25.0										
-8	0.92	25.0			100	230	270	18.32	5	3		
PB-2		25.0			220	260	234					
FB-3		18.0			0.4	3.8	0.59	7.16	3	1		
-4		18.5			90.0	115	94.0	9.42	8	6		
-5		21.0			77.5	103	144	9.00	4	1		
-6	5.4	23.5			93.0	68	96.5	47.93	14	2		
CC-7a		19.5		5.2	0.55	0.48	35.3					
-7	137	20.0		5.2	0.28	0.36	15.5					
-8		20.0		5.6	0.90	0.39	1.04	9.74	10	9		
-9	142	20.0		4.4	4.8	3.8	5.60	17.25	8	1		
-10		20.0		5.2	3.6	3.6	4.25	8.81	4	1		
-11		20.5		6.4	3.3	3.8	3.54	8.44	11	11		
-12N		20.5		4.0	2.6	4.5	3.21	10.52	4	1		
-12S		20.5		4.0				17.33	8	1		
CK-13		22.0		0.0	3.8	0.02	4.82	58.02	20	1		

SUMMARY OF OBSERVED DATA

October 16, 1968

Station	Flow Rate (cfs)	Temp. °C	Ph	DO (mg/l)	NH_3-N (mg/l)	(NO_2-NO_3)-N (mg/l)	Kjeldahl N (mg/l)	COD (mg/l)	TOC (mg/l)	TIOC (mg/l)	Phenols ppb	Alk. ppm
FCA-1	0.64	32.5	7.8		130	50.0	136					
-2	0.24	36.0	7.8		55.0	420	75.0					
-3	0.88	37.0	8.2		60.0	145	124					
-4	0.05	33.5	7.9		980	940	1050					
-4a		52.0	7.8		985	900	1012					
-4b		52.5	7.7		800	690	820					
-5		31.0	8.8		235	245	250					
-6	0.82	28.0	8.1		240	250	256					
-7	0.11	22.0	3.8		8.0	17.8	9.0					
-7a		23.0	2.9		21.6	52.7	40.0					
-8	1.11	21.5	7.7		400	430	472					
PB-2		24.0	7.7		230	280	518				5	69
FB-3		10.0	7.5		0.40	3.8	0.72				5	69
-4		22.5	7.1		91.0	105.0	91 .0					
-5		20.0	7.4		83.0	110.0	148.0					
-6	5.4	20.5	8.6		105	80.0	108				5	238
CC-7a		20.0	7.3	4.8	0.28	0.27	20.3					
-7	140	19.5	7.7	4.5	0.76	0.80	1.16					
-8		20.0	7.6	4.7	0.77	0.46	0.86				6	136
-9	145	20.0	7.8	4.1	3.8	3.3	4.40				10	136
-10		19.5	7.8	4.7	3.4	3.6	4.30					
-11		20.0	8.0	5.1	3.0	3.6	3.10				14	133
-12N		21.0	7.7	3.4	2.8	4.0	3.56					
-12S		21.0	7.7	3.0	2.6	3.5	3.87				8	136
CK-13		22.0	7.7	0.2	3.3	0.06	4.39				26	174

SUMMARY OF OBSERVED DATA

October 17, 1968

Station	Flow Rate (cfs)	Temp. °C	Ph	DO (mg/l)	NH_3-N (mg/l)	(NO_2-NO_3)-N (mg/l)	Kjeldahl N (mg/l)	COD (mg/l)	TOC (mg/l)	TIOC (mg/l)	Phenols ppb	Alk. ppm
FCA-1	0.73	35.0	8.0		110	55.0	130					
-2	0.09	30.0	9.3		575	200	590					
-3	0.82	35.0	8.5		160	75.0	167					
-4	0.08	46.0	2.0		860	1625	938					
-4a		50.0	2.2		750	1345	778					
-4b		53.0	7.4		340	305	352					
-5		31.0	3.3		290	330	315					
-6	0.84	30.0	3.2		270	350	275					
-7	0.11	22.0	3.4		1.8	23.9	3.5					
-7a		23.5	5.5		21.2	16.8	37.0					
-8	0.24	23.5	7.5		230	260	320					
PB-2		22.5	7.4		270	320	559				5	72
FB-3		18.0	7.0		1.60	4.8	1.78					
-4		18.0	7.2		92.0	105	94.0					
-5		20.3	7.2		92.0	125	93.0					
-6		21.0	8.6		102	73.0	102				15	219
CC-7a		20.0	7.2	5.0	0.74	0.82	13.5					
-7	133	20.0	6.9	4.5	0.29	0.24	0.86					
-8		20.0	7.2	5.0	0.73	0.40	0.86				6	140
-9	138	20.0	7.6	4.3	4.2	3.40	5.20				5	140
-10		20.0	6.9	4.3	3.6	3.6	4.55					
-11		20.0	7.6	4.6	-	-	-				6	136
-12N		20.5	7.6	3.4	2.4	3.7	2.96				6	142
-12S		20.5	7.6	3.0	2.5	3.6	3.20				6	142
CK-13		23.0	7.5	0.0	4.2	0.05	5.46				33	142